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THESIS

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COMPUTER SIMULATION MODEL FOR STUDYING AIRCRAFT TAKE-OFF SCHDULES AT A TRAINING AIR FORCE BASE

by

Dimitris G. Macropoulos

March 1988

Thesis Advisor: A. F. Andrus

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Computer Simulation Model for Studying Aircraft Take-off Schedules at a Training Air Force Base

by

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Captain, Hellenic Air Force
B.S., Hellenic Air Force Academy, 1978

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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March 1988

ABSTRACT

This thesis presents a computer simulation model for studying take-off schedules at Kalamata Air Force Base in Greece. Six aircraft take-off schedules were examined and a comparison of results was based upon factors of performance and efficiency/safety. The overall simulation model can be easily modified to examine other aircraft take-off schedules.

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I. INTRODUCTION

THE PROBLEM

Air Traffic Control has become a safety issue of great importance during the last decade because of the many near-miss or tragic accidents that have occurred at military and civilian airports worldwide. The main reasons for these accidents are:

- Air Traffic Control system failure,
- Air Traffic Control erroneous procedures,
- Pilot error,
- Weather conditions,
- Increased air traffic.

This issue has even greater significance at military air training bases because of the very high ratio of student pilots to experienced pilots that are using the air space and because of the large volume of aircraft activity in the air in specific areas. It is standard military training practice for a large number of training aircraft to be assigned to the same radio channel for aircraft-to-aircraft and for aircraft-to-air traffic controller communications and to have a large number of training aircraft following approximately the same air pattern with the same air speed and altitude. These conditions can increase the probability of breakdowns in synchronization and communication between aircraft and between the aircraft and the air traffic controllers and can therefore increase the probability of accidents occurring.

Kalamata Air Force Base is an Air Force training base located in southern Greece. This Base utilizes two types of aircraft for training purposes, T-37's and T-2's. The two different types of aircraft used at Kalamata Air Force Base ordinarily have different flight schedules, flight capabilities, and training missions that would allow them to take-off and begin their training flights at different times. However because of current operational constraints it is common for a group of T-2 and T-37 aircraft to complete their missions at approximately the same time so that they simultaneously return to the local Air Traffic Pattern. It is during the simultaneous approach of the returning aircraft that a critical safety problem arises due to the traffic congestion and pilot fatigue. Furthermore, the inefficient aircraft schedules interfere with the performance of the scheduled activities. A more efficient scheduling of aircraft take-offs can remedy the safety problems and also can diminish the necessity for aircraft to wait in order to get into the mission areas.

This thesis provides a computer simulation model programmed in GPSS for the IBM-PC for analyzing current procedures for the efficient management and control of the air traffic of Kalamata Air Force Base. The thesis contains the model logic, the GPSS program, model validation and model results.

II. MODEL DEVELOPMENT

A. DESCRIPTION

The environment that is modeled is the operation of the Kalamata Air Force Training Base in Greece. This operation is modeled as a sequential multiserver limited capacity queuing system. The server elements of the model consist of the base, two runways, an air traffic pattern and eight training mission areas.

The base, runways and air traffic pattern are illustrated in Figure 2.1. The air traffic pattern is modeled as a set of sequential servers consisting of two entrance points (EP1 and EP2), the initial point (IP), the low initial point (LIP), the break point and the base key. EP1 is the entrance point for the aircraft returning from a western mission area and EP2 is the entrance point for aircraft returning from an eastern mission area.

The mission areas are represented in the model as single points. Specific mission area training activity is not modeled. The eight mission areas are the neighboring areas around the airport and are illustrated in Figure 2.2. The areas west of the airport are numbered one through four and the areas east of the airport are numbered five through eight.

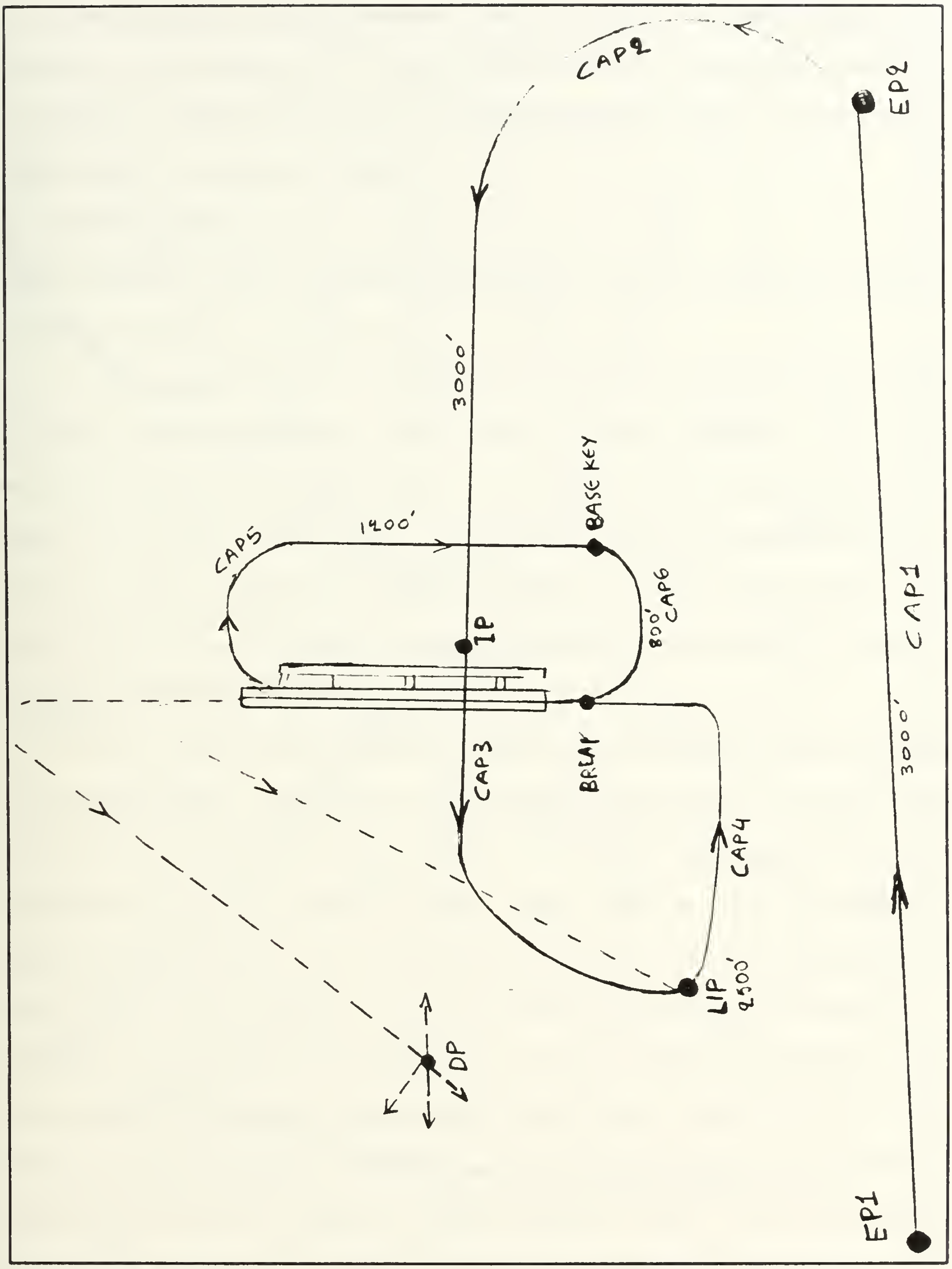


Figure 2.1 Air Traffic Pattern

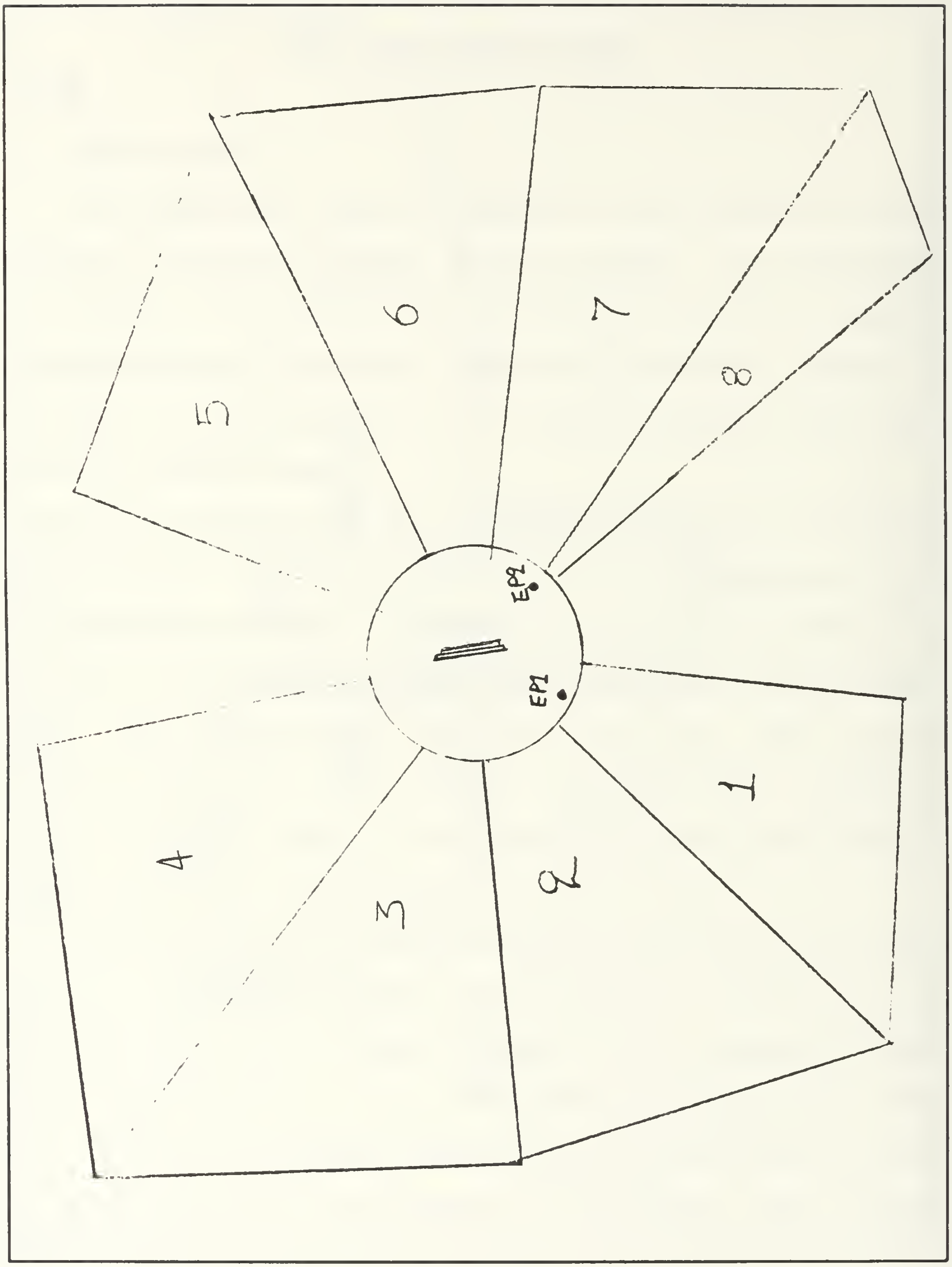


Figure 2.2 Mission Areas

The calling population consists of a basic training squadron employing T-37 type aircraft an advanced training squadron employing T-2 type aircraft and occasional aircraft from other bases.

B. MODEL LOGIC

The general flow through the model for a typical aircraft is as follows:

A take-off time is scheduled for the aircraft from one of the two squadrons and the aircraft enters the base activity queue at that time. If there is no runway or air space conflict with other aircraft landing or taking-off, the aircraft takes-off and proceeds to the base departure point where it requests and is assigned to a mission area to carry out the scheduled training activities.

If all training mission areas are occupied the aircraft is assigned to the mission training area with the smallest waiting line and in the case of ties the aircraft is assigned to the mission area with the earliest expected departure time for the occupying aircraft. All the aircraft that wait for a mission area to become available, maintain a maximum altitude of 7000 feet at the corresponding areas and perform training maneuvers consistent with the altitude safety requirements. Once the aircraft enters the mission training area it stays in the mission area for a standard length of time for the aircraft type and performs the scheduled activities.

At the completion of the mission area training activities the aircraft returns to the base and enters the returning air traffic pattern and follows the sequence of events as described below and illustrated in Figure 2.1.

Aircraft returning from the western mission areas enter the air traffic pattern at entrance point EP1 and aircraft returning from the eastern mission areas enter the air traffic pattern at entrance point EP2. The sequence of air legs in the base air traffic landing pattern and the aircraft capacity of each air leg is as follows.

Air Leg	Aircraft Capacity
EP1-EP2	2
EP2-IP	2
IP-LIP	2
LIP-Break Point	3
Break Point-Base Key	3
Base Key-Final	2

If any of the first four air legs is at full capacity when an aircraft attempts to enter, the aircraft must orbit at the air leg entry point and wait for entry. If the Break Point-Base Key leg is at full capacity when an aircraft attempts to enter, the aircraft attempting entry returns to the LIP-Break Point air leg entry point. If the Base Key-Final leg is at full capacity when an aircraft attempts to enter, the aircraft attempting entry performs "go around", that is, it cancels the landing and attempts a "close approach" pattern.

Aircraft in the "close approach" pattern re-enter the air traffic pattern at the Base Key point if no other aircraft is in the Break point-Base Key air leg and if no other aircraft is waiting for take-off. Otherwise they re-enter the air traffic pattern by joining the waiting line at the LIP entry point.

Upon being cleared for landing the aircraft will either land and return to the squadron or if flying constraints allow the aircraft will perform a touch and go landing. If a touch and go landing is made the aircraft will either enter the "close approach" pattern or attempt to re-enter the air traffic pattern with associated probabilities of 0.20 and 0.80. If there is a waiting line at the LIP point or if the IP-LIP air leg is at full capacity the touch and go aircraft will either continue to LIP or re-enter the air traffic pattern at the EP1 entry point with associated probabilities of 0.70 and 0.30.

It is also possible that the flow of aircraft in the air traffic landing pattern can be interrupted by emergency events. Emergency events such as engine failure, oil pressure failure, low fuel, or landing gear failure, are common occurrences that require the aircraft with the emergency to land as soon as possible. When such an emergency event occurs, the aircraft with the emergency preempts all other aircraft in the landing pattern. During the emergency the nonemergency aircraft in the landing pattern upon reaching the IP, LIP, or Break air leg points leave the pattern and return to the entrance point EP1 and join the orbiting waiting line. If a nonemergency aircraft is on the Base-Final air leg when the emergency situation arises the aircraft continues and makes a full stop landing.

During the emergency the aircraft present in the mission areas do not leave their areas but after completing their scheduled activities orbit at a lower altitude until the emergency ends to avoid interfering in the local traffic pattern. Aircraft returning to the air traffic pattern will not enter the pattern but will orbit at the entrance point until the emergency ends.

If an aircraft take off is scheduled during an emergency event the take-off is delayed until the emergency event is completed.

C. INPUT AND OUTPUT

All input data for the model as well as suggestions for model structure was provided by the instructor pilots and from the control tower personnel at the Kalamata Air Force Base. The general inputs to the model consisted of individual aircraft characteristics and performance data, alternate take off schedules, mission area constraints, time distributions for assignments in the mission areas, and the time distances between the reference points for the air legs in the air traffic pattern.

The model outputs contain information pertaining to the aircraft of each squadron, the air traffic pattern and mission area utilization. The following output is available.

1. Aircraft total flight time distribution.
2. Number of aircraft by squadron in the east and the west mission areas.
3. Number of aircraft take-offs.
4. Number of entries in each mission area.
5. Number of entries in each leg of the air traffic pattern.
6. Maximum number of aircraft waiting in each queue.
7. Average wait time for each queue.
8. Waiting time distributions for the following queues:
    a. Air traffic controller.
    b. Entry points, EP1 and EP2.
    c. Initial point, IP.
    d. Low Initial point, LIP.

III. GPSS APPLICATION

A. BRIEF GPSS DESCRIPTION

GPSS is the General Purpose Simulation System language developed by IBM for modeling and simulating queuing systems. GPSS was used to model the Kalamata Air Force Base air traffic operations. The GPSS program is included in Appendix A.

GPSS uses the process interaction approach for modeling in which the model entities are either temporary or permanent. The temporary entities are called transactions and the permanent entities are called facilities and storages. The transactions represent the calling population and the facilities and storages represent the service centers. Transactions interact with other transactions and with the facilities and storages. In the Kalamata Air Force Base model the calling populations of aircraft are represented by transactions and the mission areas and the air traffic landing pattern segments are represented by facilities and storages.

The modeling and programming approach in GPSS is to define a set of programming statements called blocks that represent the entrance and flow of the transactions into the queuing system composed of the facilities and storages. There can be many transactions simultaneously moving through the blocks. At any point in time each transaction is positioned at a block and most blocks can hold many transactions simultaneously. The transfer of a transaction from one block to another occurs instantaneously at a specific time or when some change of system condition occurs. Time in the GPSS model is managed by the next event sequence with the simulation clock changing at nonuniform discrete time points when the state of the system changes. Transactions continue to move through the system until they either encounter a waiting line or service time delay.

In GPSS simulated clock time is an integer value whose scale value is chosen by the programmer. The unit of time is not specifically stated but is implied by providing all times in the same units. In the Kalamata Air Force Base model the unit of time used is the second.

B. MODEL STRUCTURE IN GPSS

A brief description of some of the important programming blocks and storage areas used in the GPSS Kalamata Air Force Base model are contained in this section.

GENERATE and TERMINATE blocks: Transactions are created and enter the system at one or more GENERATE blocks and are removed from the simulation at TERMINATE blocks.

The time and frequency with which transactions enter the system are controlled by the GENERATE block. In the Kalamata Air Force Base model GENERATE blocks are used for the entry of training aircraft from the squadrons for take off assignments and for the entry of occasional aircraft from other bases into the Kalamata air traffic landing pattern.

ADVANCE block: The ADVANCE block will hold transactions for a specified or computed number of time units. The purpose of the ADVANCE block is to hold the transactions in service. In the Kalamata Air Force Base model ADVANCE blocks are used to simulate the time delays associated with take off delays, training mission areas and transit from point to point in the air leg segments of the air traffic landing pattern.

TEST block: The TEST block is used to manage or transfer transactions based upon the test conditions. In the Kalamata Air Force Base model the TEST block is used to prevent aircraft from entering the system after the daily training period and to assure that the aircraft in the system are correctly processed in order to complete all landings after the daily training period ends.

GATE block: The GATE block is used as a gate to interrupt the flow of transactions depending upon conditions that set the gate to "open" or "closed". In the Kalamata Air Force Base model GATE blocks are used to prevent aircraft from continuing in the air traffic landing pattern or the take-off queue during an emergency event.

SELECT block: The SELECT block is used to direct the flow of transactions. In the Kalamata Air Force Base model SELECT blocks are used to assign the aircraft to the training mission areas after take-off.

JOIN, REMOVE, COUNT and MARK blocks: The JOIN, REMOVE, COUNT and MARK blocks are used to collect, remove, count and identify transactions in the queue. In the Kalamata Air Force Base model if the training mission areas are occupied the JOIN, REMOVE, COUNT and MARK blocks are used to determine current aircraft assignments based upon the shortest waiting lines for the areas.

FACILITIES and STORAGE areas: GPSS FACILITIES and STORAGE areas are used to collect and hold transactions for time delays that can be associated with service or performance of the transactions. A GPSS FACILITY can hold one transaction. A GPSS STORAGE area can hold more then one transaction. In the Kalamata Air Force Base model eight FACILITIES model the eight mission areas, one FACILITY models emergency aircraft, one FACILITY models the air traffic controller, four facilities model aircraft synchronization, and six STORAGE AREAS have been used to model the air leg segments of the air traffic landing pattern as described in the following page.

FACILITY	MODEL
101	Mission area 1.
102	Mission area 2.
103	Mission area 3.
104	Mission area 4
105	Mission area 5.
106	Mission area 6.
107	Mission area 7.
108	Mission area 8.
DANGER	Emergency aircraft.
CNTR	Traffic controller.
DUMY1	Aircraft synchronization.
DUMY2	Aircraft synchronization.
DUMY3	Aircraft synchronization.
DUMY4	Aircraft synchronization.

STORAGE AREA	Air Leg Segment
CAP1:	EP1-EP2
CAP2:	EP2-IP
CAP3:	IP-LIP
CAP4:	LIP-BREAK POINT
CAP5:	BREAK POINT-BASE KEY
CAP6:	BASE-FINAL

C. GATHERING STATISTICS WITH GPSS

GPSS automatically records data and collects queue statistics for transactions that pass through a storage area. In addition to the previously described GPSS programming blocks that manage the flow of transactions there are several block types that are specifically designed to gather statistics on transactions. These blocks and their application are described in this section.

QUEUE and DEPART statistic blocks: QUEUE and DEPART blocks are used to identify specific data collection points in the queue.

Data on transactions that move through the queue and enter and leave associated QUEUE and DEPART blocks is collected as separate sets of queue statistics. In the Kalamata Air Force Base model queue statistics were accumulated over the entire period of the simulation, in each queue of the air traffic pattern and in each queue of the mission areas. The accumulated statistics for each of the model queues are identified in the following list.

Queue Statistics

Maximum number of aircraft.

Average number of aircraft

Standard deviation of the number of aircraft.

Average waiting time.

Number of entries.

Number of entries that did not wait for entry.

Average wait time to enter the queue.

TABULATE, TABLE and QTABLE statistic blocks: The TABULATE, TABLE and QTABLE blocks are used to collect data for frequency and cumulative frequency tables. The TABLE and QTABLE blocks define the transaction characteristics that are to be counted and the range of the frequency tables. Data on characteristics of the transactions that pass through a TABULATE block are automatically collected. The TABULATE block may be used anywhere in the GPSS program and can collect data on all of the transactions computed characteristics. The TABULATE, TABLE and QTABLE blocks are used in the Kalamata Air Force Base model to tabulate the total flight time distribution for the two types of aircraft and waiting time distributions for all of the model queues.

IV. MODEL VALIDATION

The Kalamata Air Force Base model was validated by comparing model output to historical data for a specific take off schedule for the squadrons of aircraft. Historical data was made available for each aircraft for a three day period. The historical data is included in Appendix C.

For each aircraft the historical data consisted of the interarrival times for take off, the time spent waiting in the air traffic controller queue, the time spent waiting to enter area 3 and the total flight time. The historical data was accumulated and averaged for the three days of base activity. Using the historical interarrival rates as model inputs the model generated waiting times and total flight times were compared to the historical data.

The historical interarrival rate appeared to be nonhomogeneous on a daily basis. Therefore the operations day was broken into time periods for which the interarrival rates were homogeneous. These time periods were:

1) 07:30 - 08:40
2) 08:40 - 09:10
3) 09:10 - 11:10
4) 11:10 - 11:40
5) 11:40 - 14:00
6) 14:00 - 14:30
7) 14:30 - 16:20
8) 16:20 - 17:30

For each time period the interarrival times appeared to have an exponential distribution. This hypothesis was tested using the Kolmogorov-Smirnov test and was not rejected. The hypothesis test results are included in appendix D. With this base information the model was run for a period of eight days using the hypothesized exponential distributions for the take off interarrival times. The validation comparison tests follow.

Figure 4.1 displays a plot of the comparison of the actual wait time with model generated wait time for entry to area 3, and Figure 4.1a displays the regression line for the regression model:

Simulated Data=A+B*(Actual Data).

The slope of the regression line is .97 with a standard deviation of .027. The hypothesis B=1 was tested with the t-test and was not rejected. The probability level for the t-statistic was .16.

Figure 4.2 displays a plot for the comparison of actual wait time with model generated wait time in the air traffic controller queue and Figure 4.2a displays the regression line for the regression model:

Simulated Data=A+B* (Actual Data).

The slope of the regression line is .98 with a standard deviation of .043. The hypothesis B=1 was tested with the t-test and was not rejected. The probability level for the t-statistic was .43.

Figure 4.3 displays a plot of the comparison of actual total flight time with model generated total flight time and Figure 4.3a displays the regression line for the regression model:

Simulated Data=A+B*(Actual Data).

The slope of the regression line is .96 with a standard deviation of .019. The hypothesis B-1 was tested with the t-test and was not rejected. The probability level for the t-statistic was .09.

These results provide a validation of the model and show that the model data compares favorably with the historical data for the specified take off schedules.

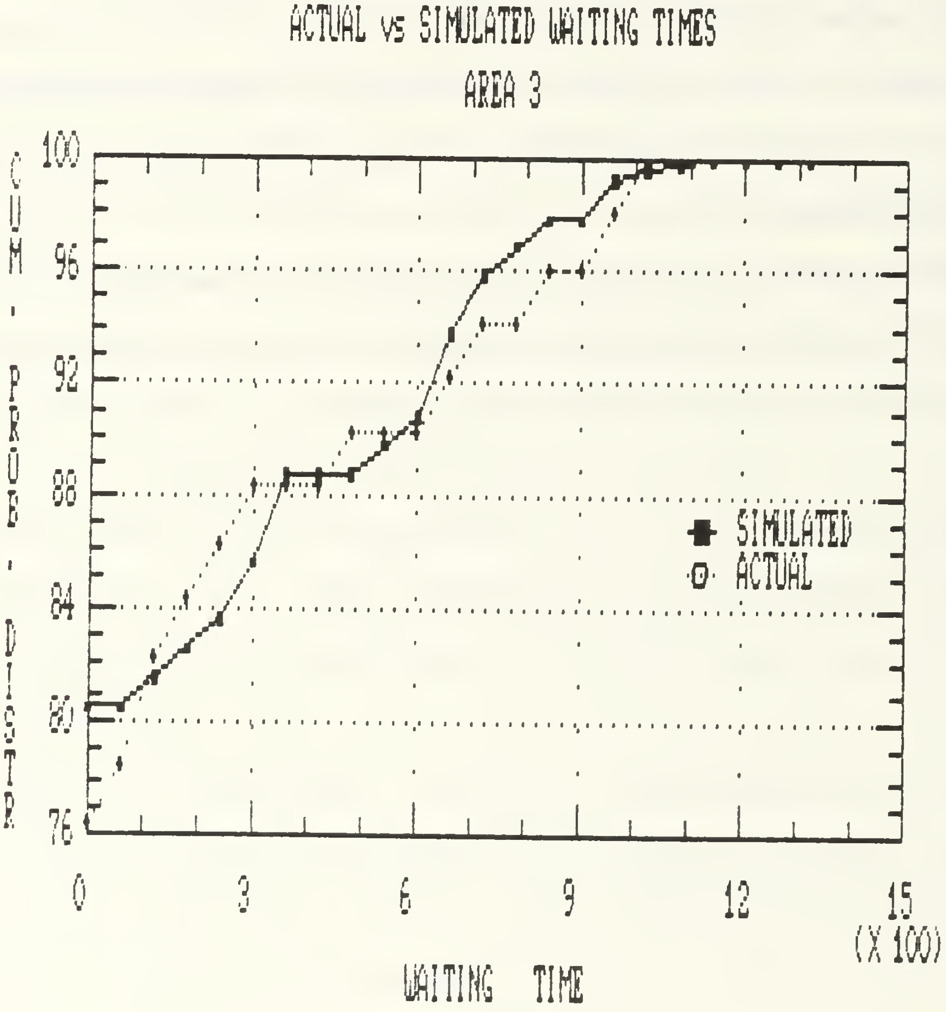


Figure 4.1 Comparison of Actual Wait Time with Simulated Wait Time in Area 3

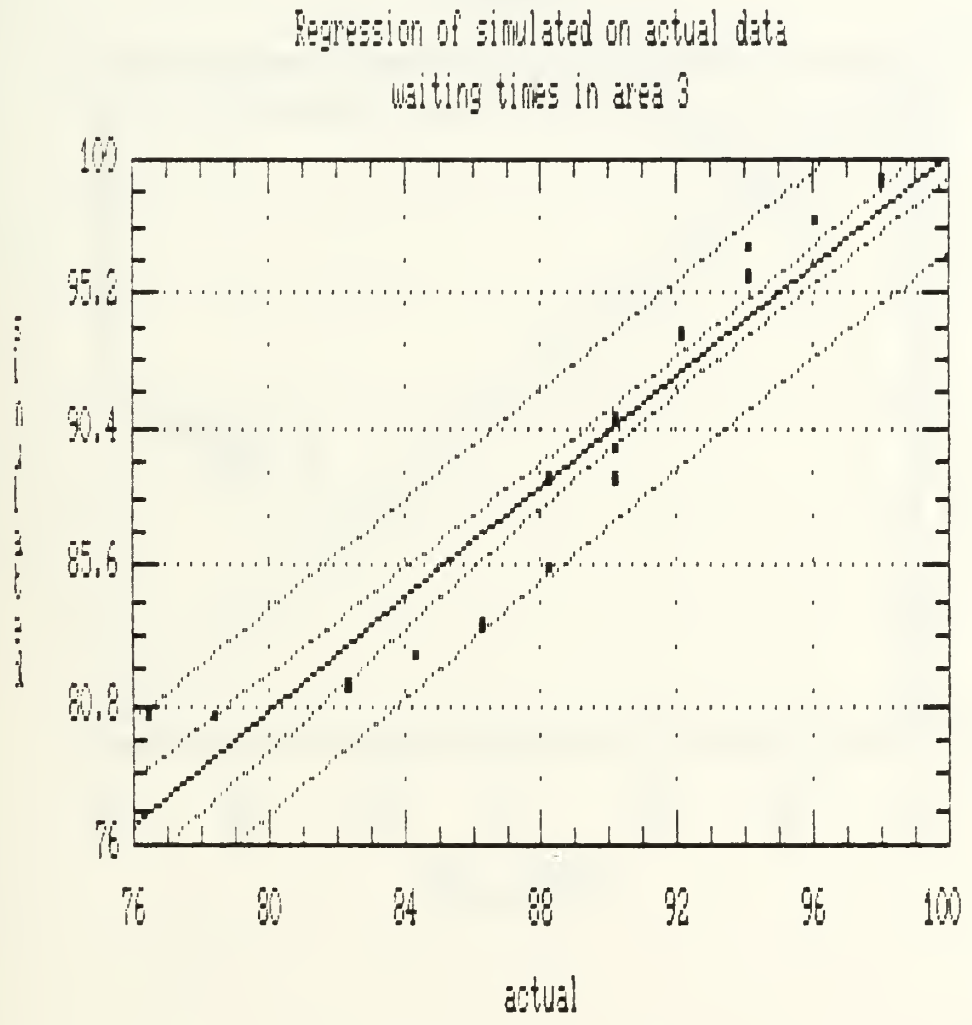


Figure 4.1a Regression of Simulated Wait Time on Actual Wait Time in Area 3

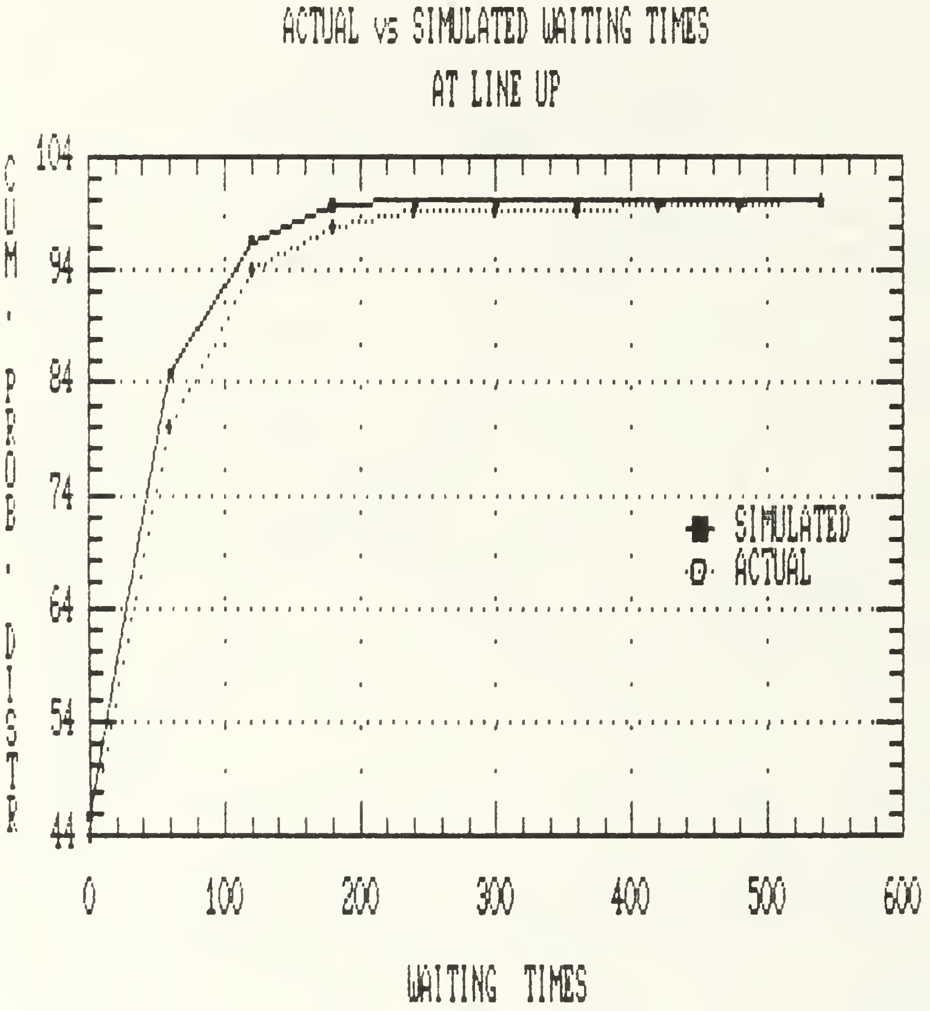
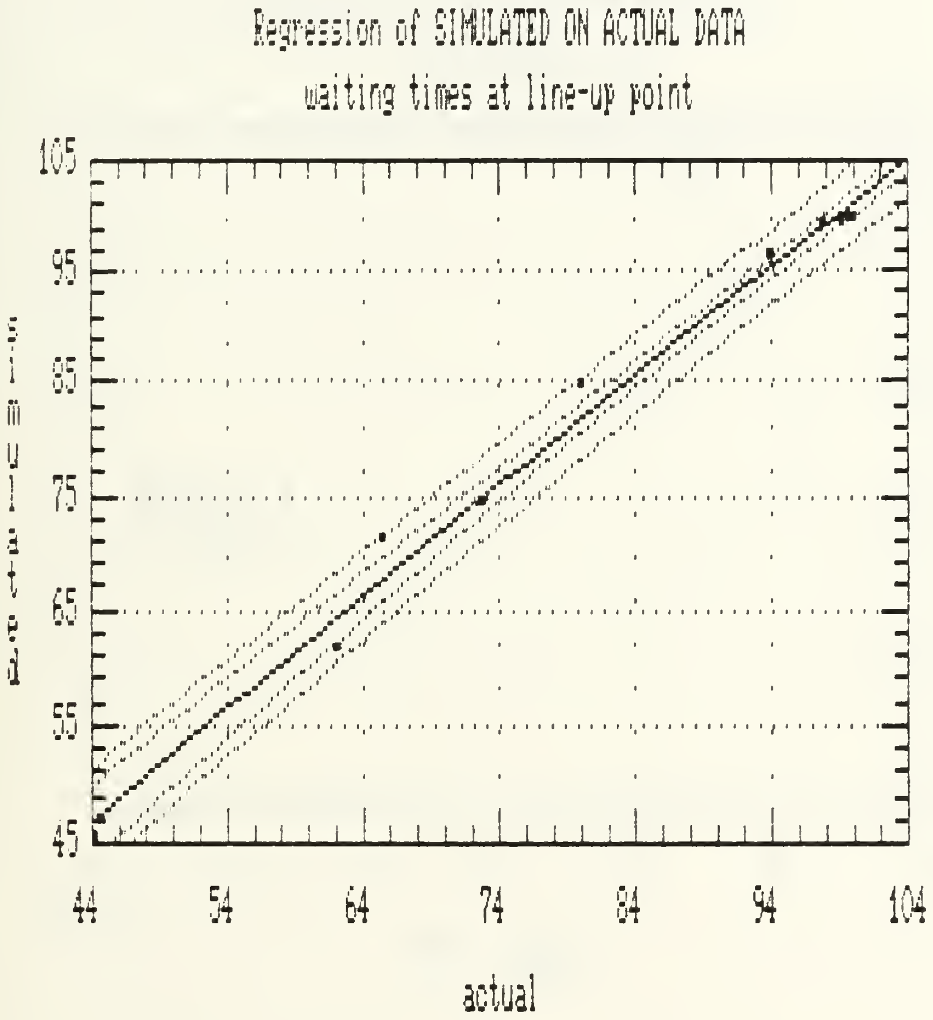


Figure 4.2 Comparison of Actual Wait Time with Simulated Wait Time at Line Up



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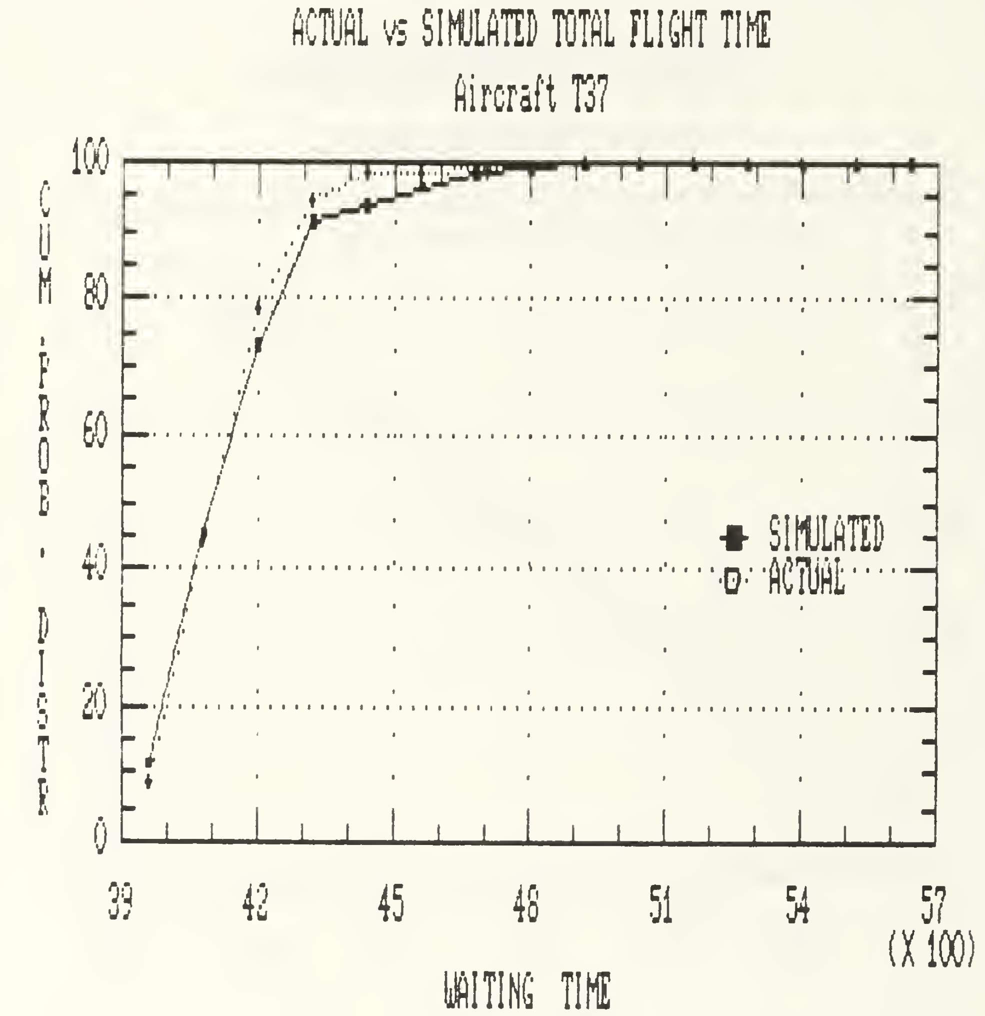


Figure 4.3 Comparison of Actual Flight Time with Simulated Flight Time

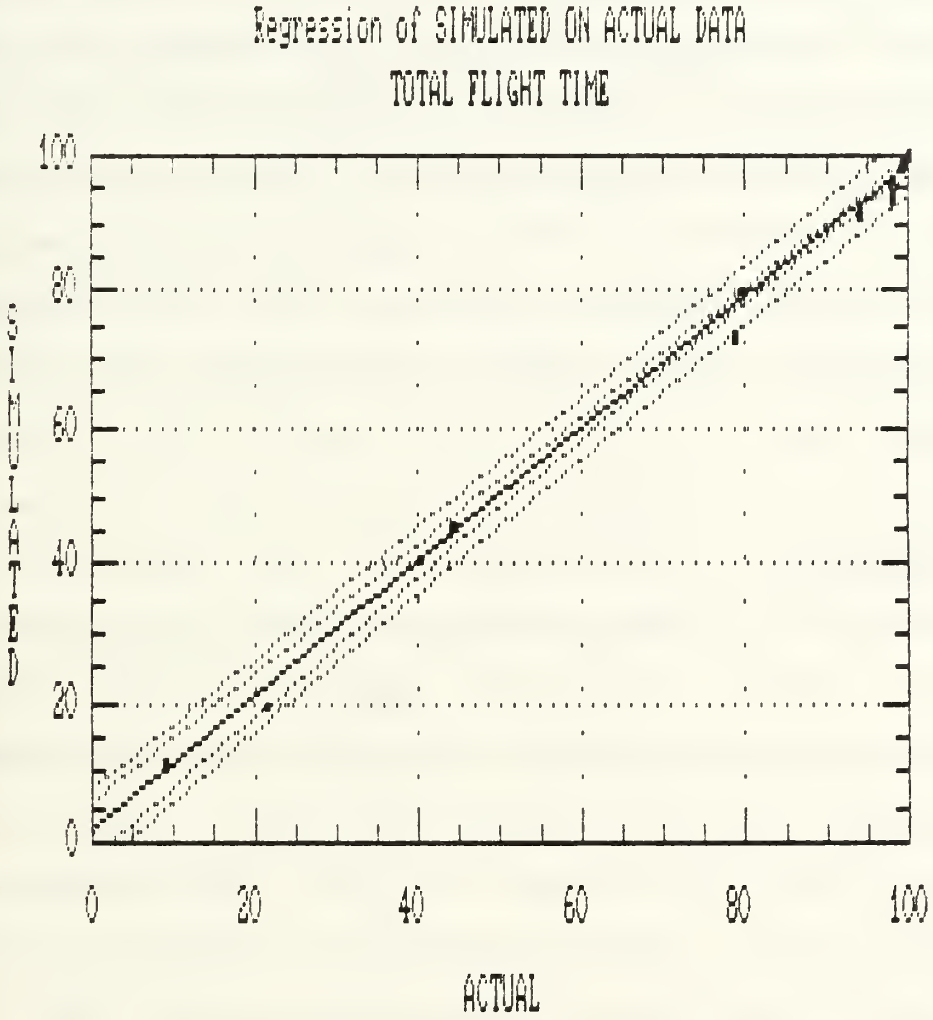


Figure 4.3a Regression of Simulated Flight Time on Actual Flight Time

V. RESULTS-ANALYSIS

This section contains a description of four basic and two additional take-off schedules for the squadron of training aircraft for Kalamata Air Force Base that were run in the model and a comparison analysis of the resulting air traffic controller congestion in order to determine a reasonable efficient take-off schedule. In order to run each take-off schedule in the model, the GPSS program had to be modified. These program modifications are included in Appendix B.

A. SCHEDULES

Schedule 1: This schedule consists of a forty minute take-off cycle. The cycle consists of two consecutive fifteen minute take-off periods followed by ten minutes of no take-off activity. The T-37 aircraft squadron assigns five aircraft for take-off in the first fifteen minute period. The T-2 aircraft squadron assigns five aircraft for take-off in the second fifteen minute period. This cycle is repeated until all the training aircraft are scheduled for take-off. Aircraft that can not take-off in their assigned period are recycled for later take-off. Aircraft taking-off have priority use of the runway over normally landing aircraft. This schedule was proposed for analysis by the two squadrons at Kalamata Air Force Base.

Schedule 1A: This schedule is derived from and is identical to Schedule 1 except that the number of aircraft scheduled for take-off in each fifteen minute period is four instead of five. This schedule was suggested as a result of reviewing the model output data for Schedule 1. It was thought that this change would decrease the number of training flights while also decreasing the air traffic congestion and waiting times.

Schedule 1B: This schedule is derived from and is identical to Schedule 1 with the take-off cycle period extended to sixty minutes. This schedule was also suggested as a result of reviewing the model output data for Schedule 1. It was thought that this change would also decrease the number of training flights while decreasing the air traffic congestion and waiting times.

Schedule 2: This schedule consists of an eight-minute take-off cycle. The cycle consists of two consecutive four-minute take-off periods. The T-37 aircraft squadron assigns one aircraft for take-off in the first four-minute period. The T-2 aircraft squadron assigns one aircraft for take-off in the second four-minute period. This cycle is repeated until all the training aircraft are scheduled for take-off. Aircraft that can not take-off in their assigned four-minute period are recycled for later take-off. This schedule was also suggested as a result of reviewing the model output data for Schedule 1. It was thought that this model output data for Schedule 1. It was thought that this change would increase the number of training flights while decreasing the air traffic congestion and waiting times.

Schedule 2A: This schedule is derived from Schedule 2 and is identical to Schedule 2 except that the take-off cycle is extended to ten minutes with two five-minute take- off periods. This schedule was suggested as a result of reviewing the model output data for Schedule 2.

Schedule 3: This schedule is a reproduction of the schedule currently in use at Kalamata Air Force Base. The schedule contains no structure and take-off times are scheduled at random. The distributions of current interarrival times for take-off times were analyzed and found to be exponential for different periods during the day. This analysis is contained in Appendix C and was also used for model validation.

B. RESULTS

The model output data for each schedule are contained in Appendix E. The measures of effectiveness used in comparing schedules were performance and efficiency/safety. Performance is measured by the average number of training aircraft scheduled. Efficiency is measured by the average waiting times in the mission area queues. Safety is directly related to efficiency in that the smaller waiting times mean less hazardous flying conditions. The empirical distributions for both of these measures for each schedule are contained in Appendix E.

The summary results for Schedule 1 are of interest because this schedule was suggested by the training squadrons at Kalamata Air Force Base. This schedule, by comparison with the other schedule results, does not provide the highest values for performance and efficiency/safety. It was because of these results that the other schedules were derived from Schedule 1 by sensitivity analysis.

The summary results for Schedule 3 are of interest because this schedule is a reproduction of the schedule currently in use at Kalamata Air Force Base. This schedule by comparison with the other schedule results, also does not provide the best values for performance and efficiency/safety.

It was found that by applying Schedule 1A and comparing the results to Schedule 1 that performance decreased but that efficiency/safety improved drastically. Figure 5.1 compares the cumulative mission area waiting time distributions and Figure 5.2 compares the cumulative LIP point waiting time distributions for Schedules 1 and 1A.

Schedule 2 results were more efficient than Schedule 1 results. However, by applying Schedule 2A mission area waiting times decreased dramatically and provided the most efficiency/safety measure for all schedules examined. Figure 5.3 compares the cumulative mission area waiting time distributions and figure 5.4 compares the cumulative LIP point waiting time distributions for schedules 2 and 2A. Figure 5.5 compares the cumulative mission area waiting time distributions for schedules 1A, 2A and 3. It is obvious that Schedule 2A is preferable to Schedule 1.

Schedule 3 results were more efficient than Schedule 1 results. The performance measure for Schedule 3 however is the lowest of all the schedules examined. Figure 5.6 compares the cumulative LIP point waiting time distributions for schedules 1A, 1B, 2A and 3.

C. ANALYSIS

From the above summary results the preferred schedules appear to be Schedules 1A and 2A. An analysis of variance was performed, using the function "ANOVA" from the OA3660 APL WORKSPACE, to test the hypothesis that the mean mission area waiting time differences for schedules 1, 1A, 2, 2A are not significant. The analysis of variance results are contained in Table 5.1. These results show that the null hypothesis of no significant differences between mean mission area waiting times is rejected at significance levels greater than .995.

The Sum of Squares from the previous analysis was broken into three components in order to test for individual effects rather than just a schedule effect using individual degrees of freedom. The results of this analysis are contained in the tables 5.2 and 5.2a. These results show that the hypothesis of no significant difference between the compared mean mission area waiting times for the selected schedules is rejected for each comparison at significance levels greater than .975.

TABLE 5.1

ANALYSIS OF VARIANCE RESULTS

```
                          ANOVA TABLE

   SOURCE        DF          SS             MS          F
   ---------------------------------------------------------

   SCHEDULE       3      232864.74     77621.59     27.77

   ERROR          4       11181.05      2795.27

   TOTAL          7      244045.78

 R-SQUARE = 0.954

 OVERALL MEAN =      200.68

 TREATMENT EFFECTS -87.56266.68***.50 14.39

  -68.5     24.02     0.435 -17.92

   68.5    -24.02    -0.435  17.92
```

TABLE 5.2

ANOVA WITH INDIVIDUAL DEGREES OF FREEDOM

SCHEDULE 1		SCHEDULE 1A		SCHEDULE 2A		SCHEDULE 2	
44.62	181.62	49.138	443.34	7.62	6.75	197.15	232.99
1	1	1	1	1	1	1	1
1	1	1	1	-1	-1	-1	-1
1	1	-1	-1	0	0	0	0
0	0	0	0	-1	-1	1	1
1	-1	0	0	0	0	0	0
0	0	1	-1	0	0	0	0
0	0	0	0	1	-1	0	0
0	0	0	0	0	0	1	-1

$D=S_{bij}^{2}$	$Z=Sb_{ij}X_j$	$w_i^{2}=Z_i^{2}/D_i$
8	--	--
8	716.45	64162.575
4	-708.48	125485.970
4	415.77	43216.173
2	-137.00	9384.500
2	48.04	1153.920
2	0.87	0.378
2	1284.50	642.250

TABLE 5.2a

ANALYSIS OF VARIANCE RESULTS USING INDIVIDUAL DEGREES OF FREEDOM

SCHEDULES	SS	DF	MS	F
(1,1A)vs(2,2A)	64162.575	1	64162.575	22.954
1 vs 1A	125485.970	1	125485.970	44.892
2 vs 2A	43216.173	1	43216.173	15.460
RESIDUAL	11181.048	4	2795.262	
TOTAL	244045.760	7		

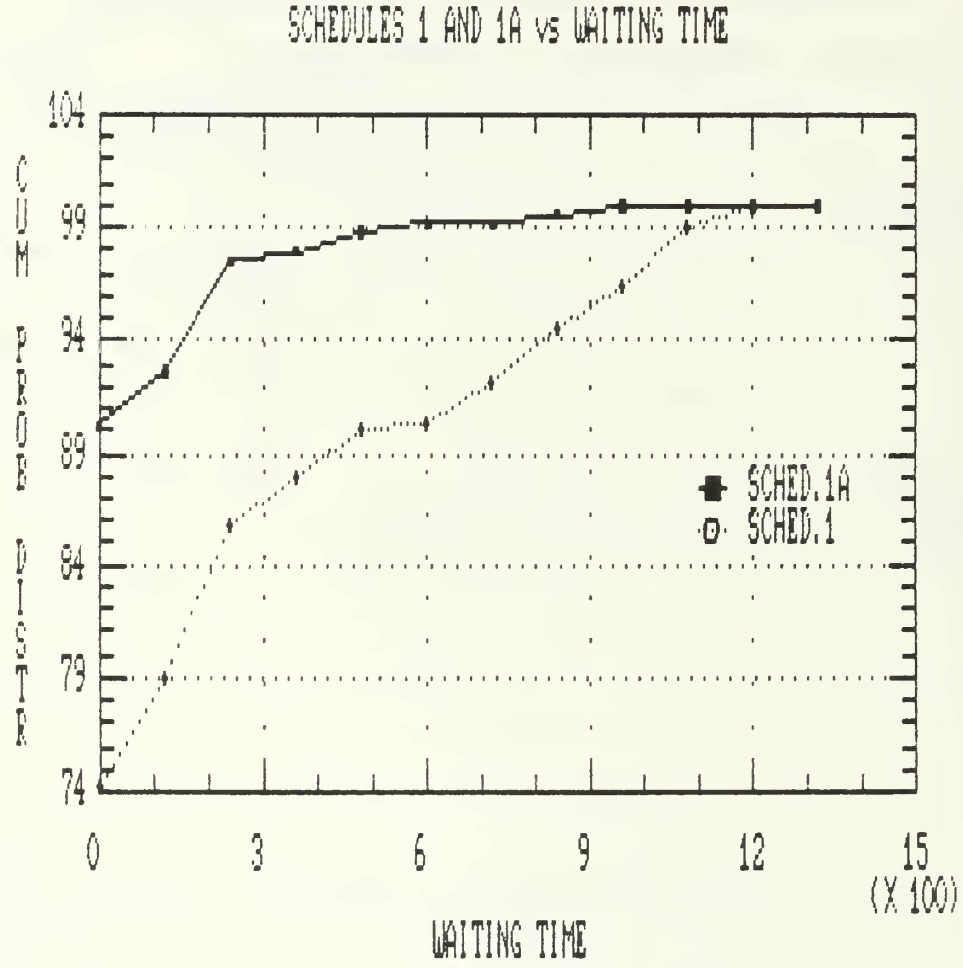


Figure 5.1 Cumulative Waiting Time Distribution

in the Mission Areas

Schedules 1 and 1A

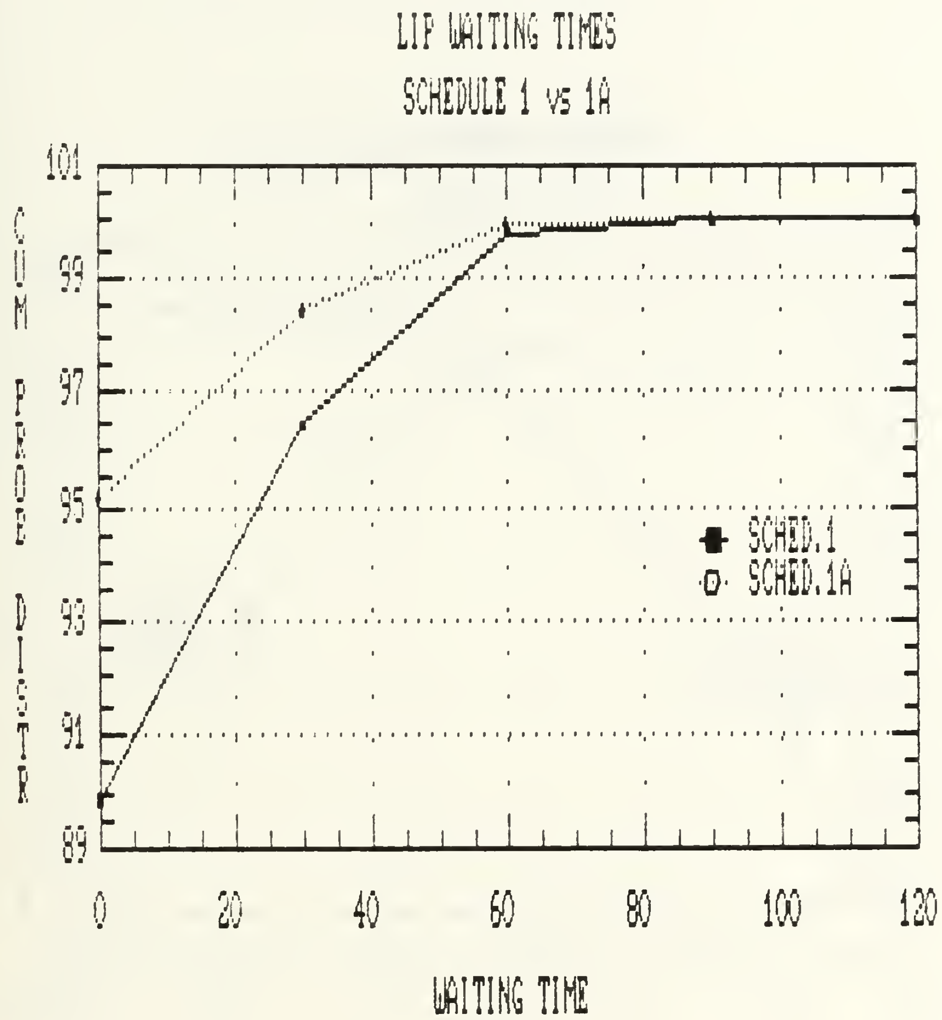


Figure 5.2 Cumulative LIP Waiting Times

Schedule 1 and 1A

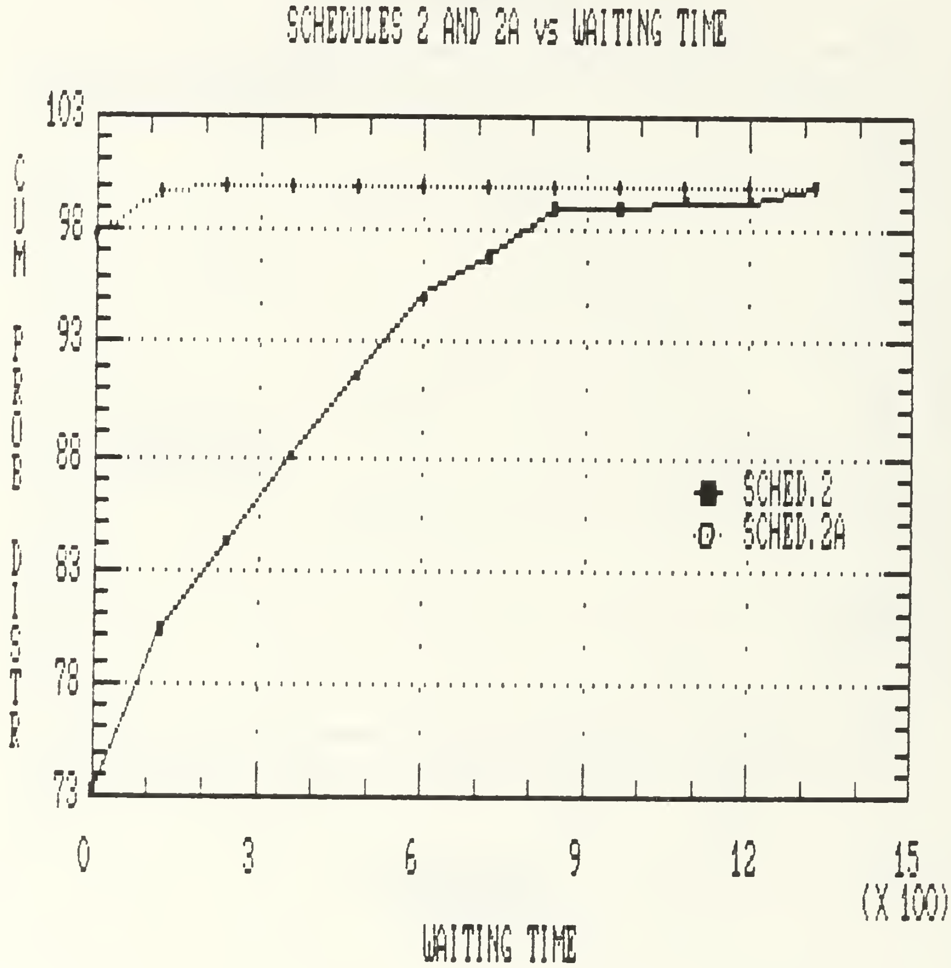


Figure 5.3 Cumulative Waiting Time Distribution in the Mission Areas Schedules 2 and 2A

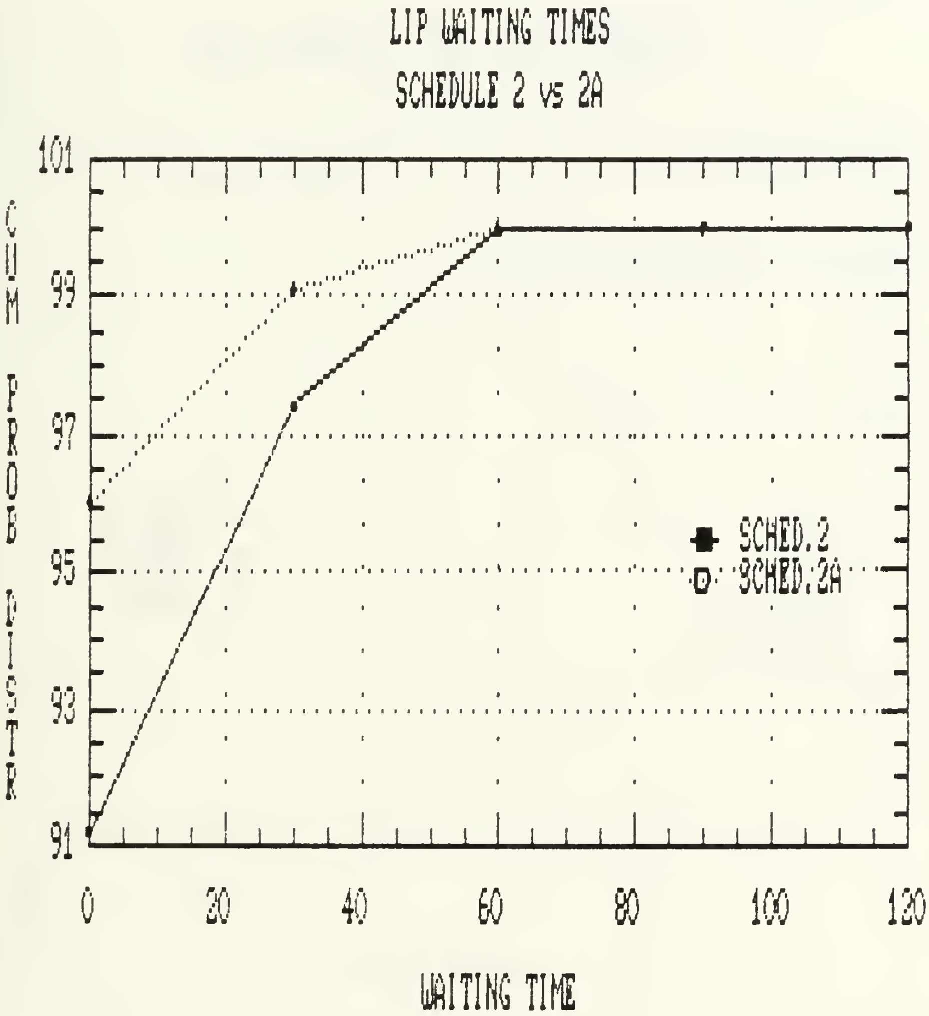


Figure 5.4 Cumulative LIP Waiting Times

Schedule 2 and 2A

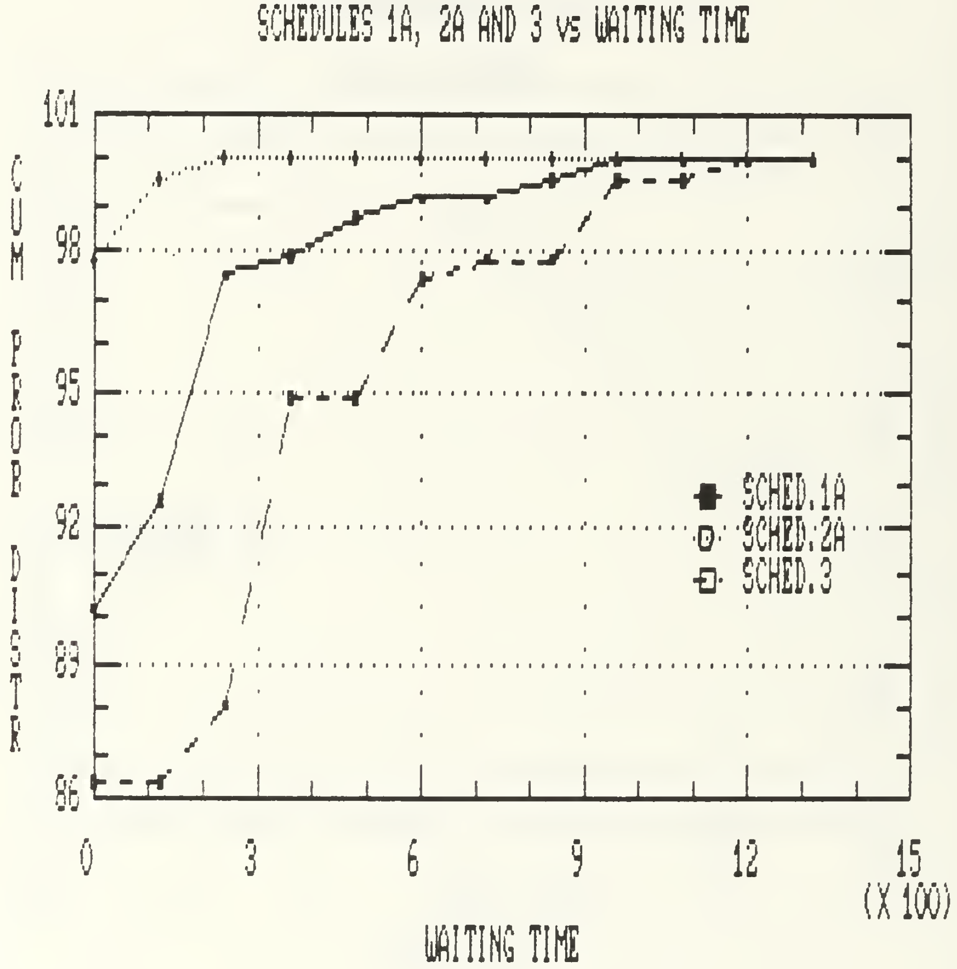


Figure 5.5 Cumulative Waiting Time Distribution in the Mission Areas Schedules 1A 2A and 3

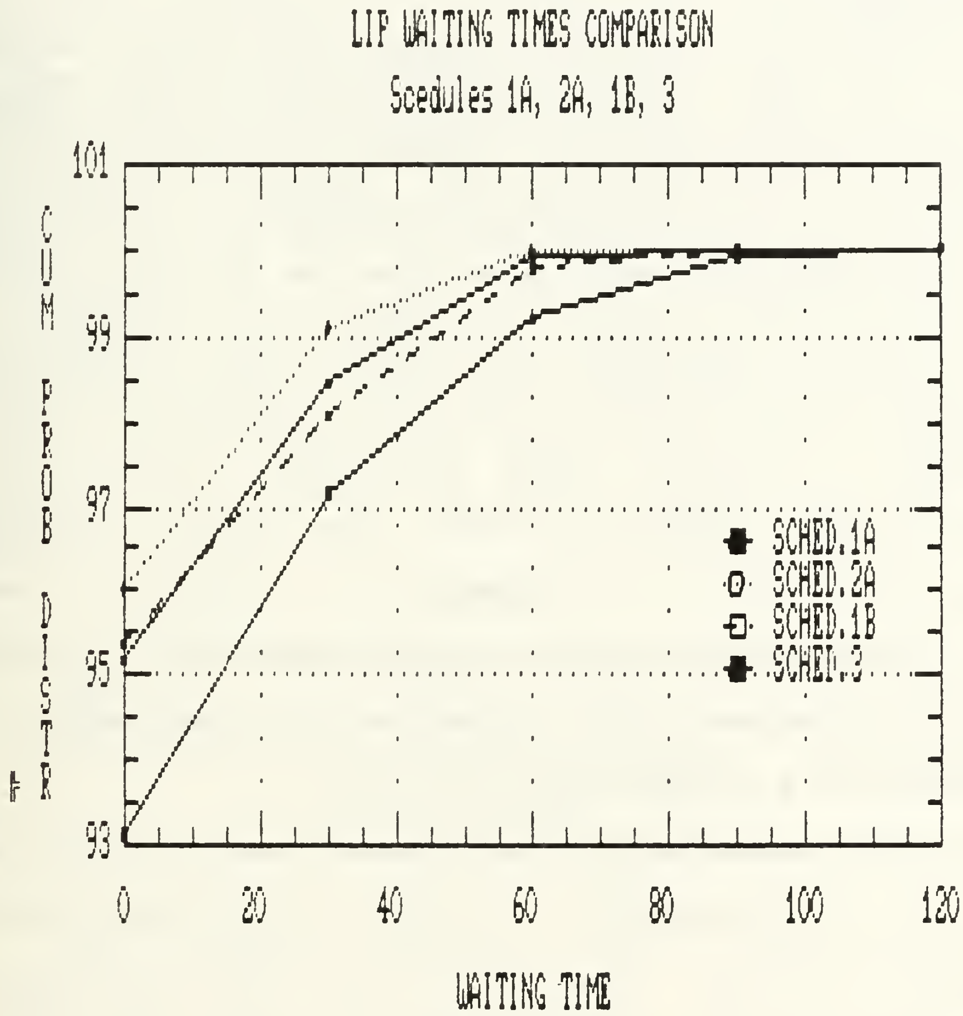


Figure 5.6 Cumulative LIP Waiting Times

Schedules 1A 1B 2A and 3

VI. CONCLUSIONS - SUMMARY

A. CONCLUSIONS

If an added emphasis is to be placed upon the efficiency/safety factor in scheduling the aircraft then Schedule 2A is the preferred schedule. If Schedule 2A conflicts with local base operations due to other operating constraints then Schedule 1A is the next best schedule. The difference in mean mission area waiting times for these two schedules is made more significant when it is also realized that landing aircraft have runway priority in schedule 2A and do not in Schedule 1A. Figure 6.1 compares the cumulative mission area waiting time distributions and figure 6.2 compares the cumulative LIP point waiting time distributions for schedules 1A and 2A.

If added emphasis is to be placed upon the performance factor in scheduling the aircraft then Schedule 2 is the preferred schedule. However, the increase of twenty four scheduled aircraft is at the expense of more than a ten fold increase in mean mission area waiting times that contributes to air traffic congestion and pilot fatigue and should be avoided if possible. Again, if Schedule 2 conflicts with local base operations due to other operating constraints then Schedule 1 is the next best schedule. It is recommended that the efficiency/safety factor be the deciding factor in selecting schedules.

Table 6.1 contains a summary comparison between the different schedules. In this table the first column contains the average number of flights, the second column contains the percentage of the aircraft that waited in the mission area queues, the third column contains the percentage of the aircraft that waited more than 180 seconds in the mission area queues, the fourth column contains the percentage of the aircraft that waited more than 30 seconds at LIP and the fifth column contains the average conditional waiting time, in seconds, in the mission area queues.

TABLE 6.1

SUMMARY COMPARISON BETWEEN SCHEDULES

	# of A/C scheduled	% of A/c waiting in m. areas	% of A/C waiting >180"in m.areas	% of A/C waiting >30"in LIP	Avg.Conditional waiting time in seconds
Sch.2A	106	2	0	0.8	11
Sch.1A	106	7	5.6	1.6	45
Sch.2	130	26	18	2.5	203
Sch.1B	89	7	7	2	230
Sch.3	99	14	13	3	368
Sch.1	130	26	17	3.5	496

Figure 6.3 compares the cumulative mission area waiting time distributions and figure 6.4 compares the cumulative LIP point waiting time distributions for schedules 1 and 2.

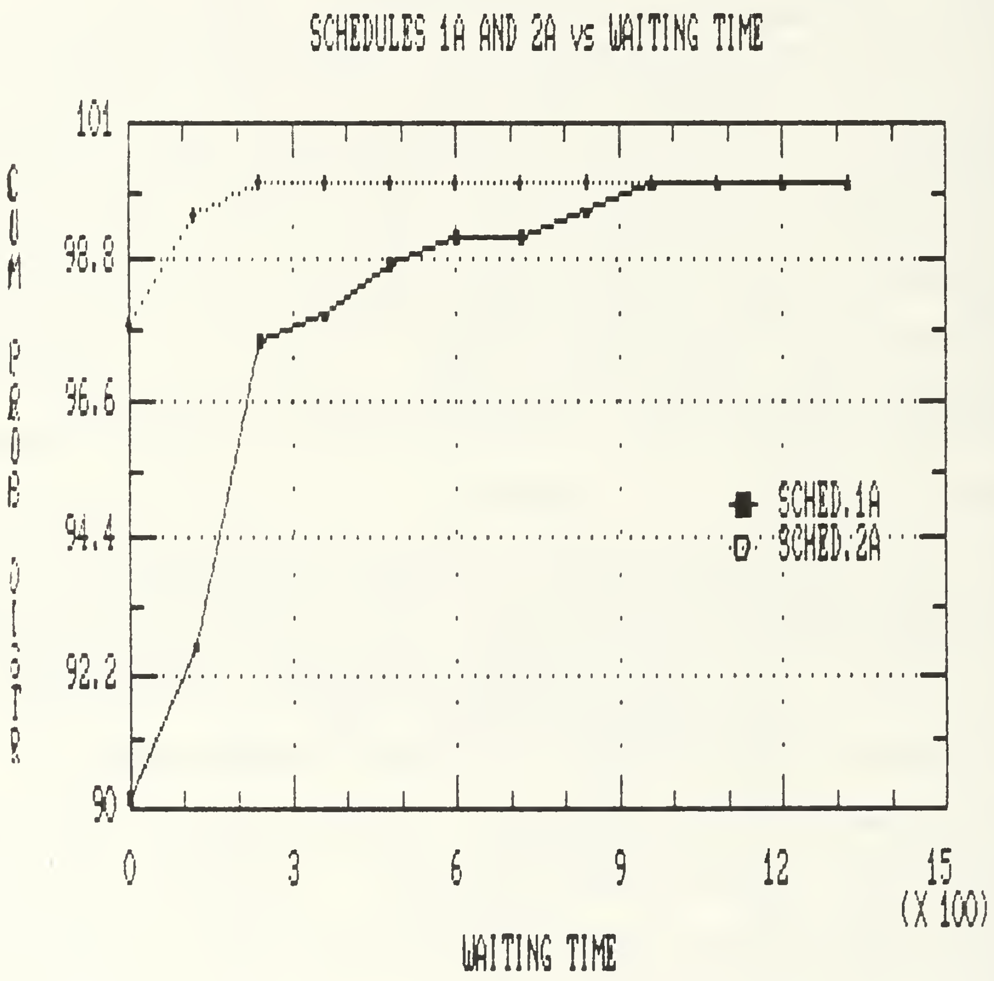


Figure 6.1 Cumulative Waiting Time Distribution in the Mission Areas Schedules 1A and 2A

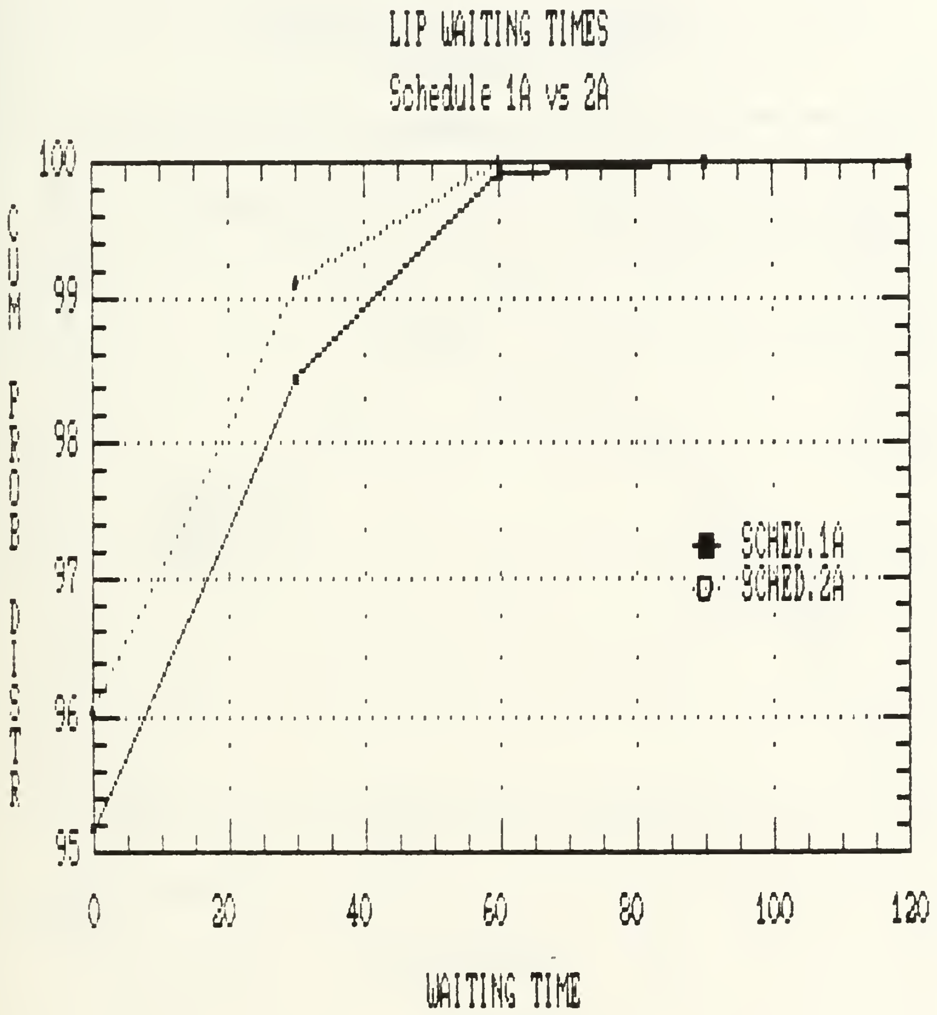


Figure 6.2 Cumulative LIP Waiting Times

Schedules 1A and 2A

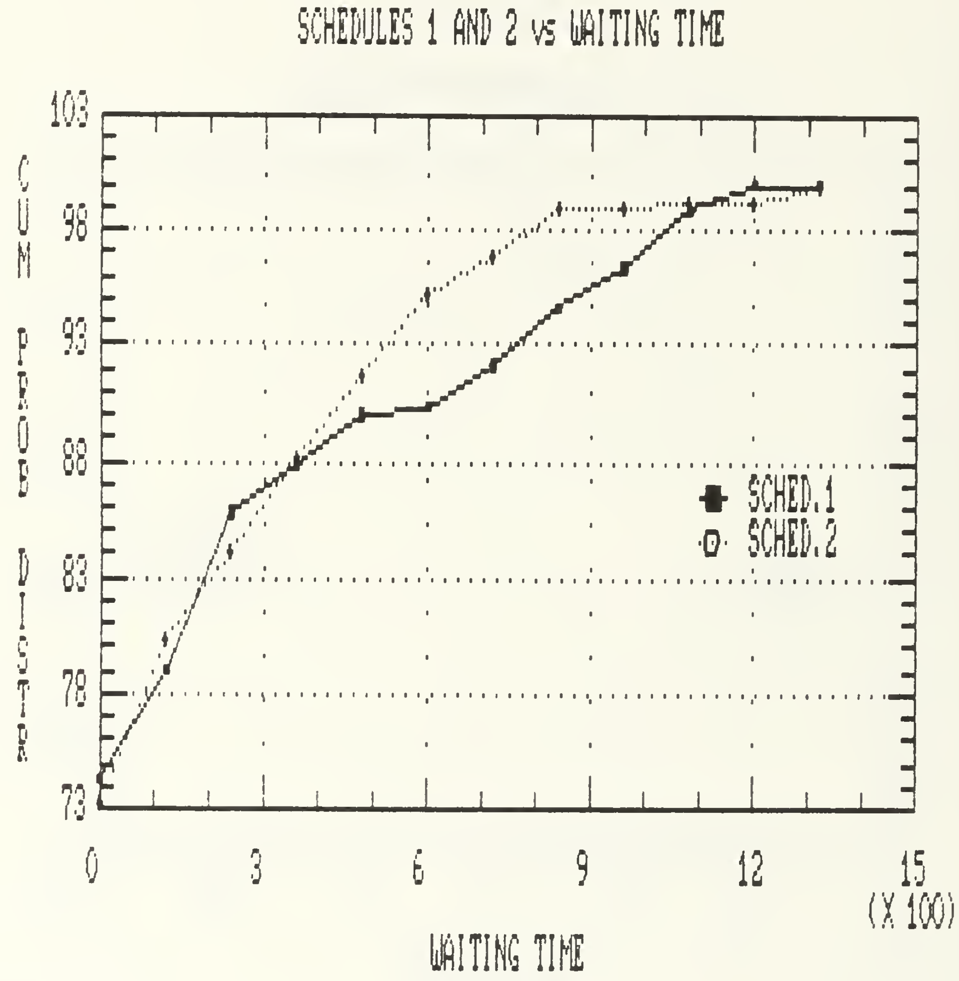


Figure 6.3 Cumulative Waiting Time Distribution
in the Mission Areas
Schedules 1 and 2

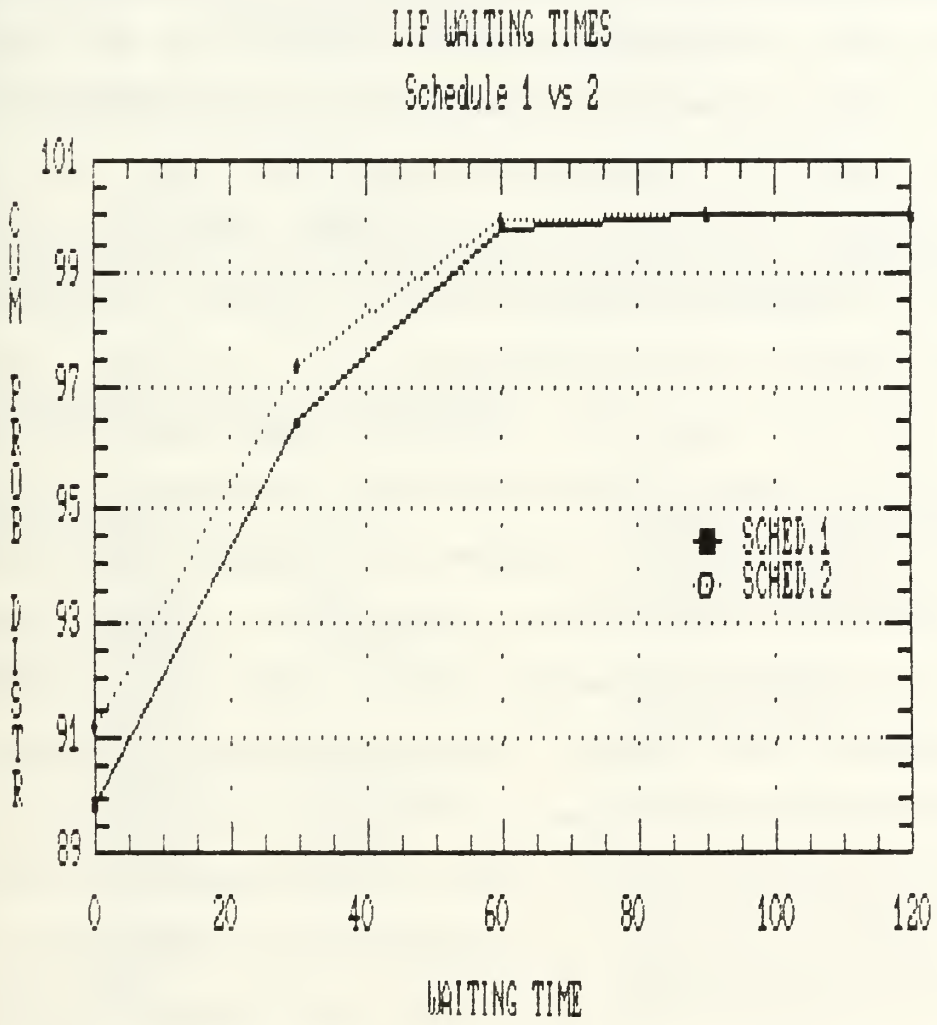


Figure 6.4 Cumulative LIP Waiting Times

Schedules 1 and 2

B. SUMMARY

This thesis presents an IBM-PC GPSS model for studying aircraft take-off schedules at Kalamata Air Force Base in Greece. The model is specific to Kalamata Air Force Base because of the structure and sequence of the queues used in modeling the air traffic control points and the training mission areas. The GPSS program can be transferred to any IBM-PC compatible computer that will run GPSS. The model can therefore be used at the Kalamata Air Force Base to continue to examine other aircraft take-off schedules and to help reducing fuel consumption.

Six aircraft take-off schedules were examined and a comparison of results was based upon factors of performance and efficiency/safety. The take-off schedule currently used at Kalamata Air Force Base is shown to be a poor performer with a low efficiency/safety factor. The take-off schedule proposed for use by the training squadron personnel at Kalamata Air Force Base is shown to have the highest performance factor and the worst efficiency/safety factor.

The specific schedule of ten minutes of a ten minute take-off cycle consisting of two consecutive five minute take-off periods from each squadron with runway priority given to landing aircraft is shown to be the best schedule based upon the recommended emphasis placed upon efficiency/safety rather than on numerical performance.

APPENDIX A

This appendix contains the GPSS program for the Kalamata Air Force Base model.

```
10 ************************************************************************
20 *                                                                      *
30 *                  AIR-TRAFFIC CONTROL  SIMULATION                     *
40 *                  -------------------------------                     *
50 *                                                                      *
60 ************************************************************************
70 *
80 *
90 *                      EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION      RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5..69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION      C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31300,494.60/36600,221.30
150 *
160 *
170             GENERATE      ,,,1                    ;CREATE A SINGLE TRANSACTION
180 SWITCH1 LOGIC S       1                       ;SET LOGIC SWITCH 1
190             ADVANCE       300                     ;T-37 TAKE OFF
200             LOGIC R       1                       ;RESET LOGIC SWICH 1
210             ADVANCE       2100                    ;NONE T-37 TAKES OFF
220             TRANSFER      ,SWITCH1
230             GENERATE      ,,900,1
240 SWITCH2 LOGIC S       2                       ;SET LOGIC SWICH 2
250             ADVANCE       300                     ;T-2 TAKE OFF
260             LOGIC R       2                       ;RESET LOGIC SWICH 2
270             ADVANCE       2100                    ;NONE T-2 TAKES OFF
280             TRANSFER      ,SWITCH2
290             GENERATE      9000,FN‡EXP             ;CREATE EMERGENCY EVENTS
300             SEIZE         DANGE
310             ADVANCE       600.180                 ;EMERGENCY HOLDS
320             RELEASE       DANGE
330             TERMINATE                             ;EMERGENCY TERMINATES
340 *
350             GENERATE      9100,FN‡EXP             ;A/C FROM OTHER BASES
360             ASSIGN        1,2                     ;ASSIGN TO A PARAMETER
370             MARK          4                       ;MARK THE TIME
380             TRANSFER      ,EPI
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
420             GENERATE      60.10                   ;CREATE T-37'S
430             TEST L        N‡GNRT,1,PISTA          ;THE SIMULATION STOPS AFTER
440             GATE LS       1,PISTA
450             ASSIGN        1,1                     ;ASSIGN TO A PARAMETER

460             TRANSFER      ,DOWN
470 *
480             GENERATE      60,10                   ;CREATE T-2'S
490             TEST L        N‡GNRT,1,PISTA
500             GATE LS       2,PISTA
```

```
510              ASSIGN        1,0                        ;ASSIGN TO A PARAMETER
520 DOWN         QUEUE         CNTR                       ;WAIT OUT OF THE RUNWAY
530              GATE FV       DANGE                      ;DONT MOVE IF EMERGENCY HOLDS
540 *            GATE SE       CAP4                       ;CHECK FOR A\C ON BASE LEG
550              SEIZE         CNTR                       ;CAPTURE THE CONTROLLER
560              DEPART        CNTR                       ;GOING FOR LINE UP
570 LINUP        ADVANCE       70,20                      ;LINE-UP CHECK
580              RELEASE       CNTR                       ;TAKE-OFF
590              MARK          6                          ;START FLIGHT TIMEFOR T-2 A/C
600              MARK          7                          ;START FLIGHT TIME FOR T-37 A/C
610              ADVANCE       100,10                     ;AFTER TAKE OFF TO DEPART POINT
615              TRANSFER      .25,,OTHER                 ;FORMATIONS, INSTR.FL., CPM
620 *
630              SELECT E      2,101,108,0,F,QUEUP         ;FIND EMPTY AREA IF EXISTS ONE
640 AREA         TEST E        BV$FIRST,1,WEST            ;CHOOSE EAST OR WEST AREA
650 *
660 *         E A S T   A R E A S
670 *
680              SAVEVALUE     13+,P1                     ;RECORDS T-37'S
690              SAVEVALUE     14+,1                      ;RECORDS TOTAL # OF A/C
700 WAIT         QUEUE         P2                         ;WAIT IN THE QUEUE
710              TEST E        P1,1,TTWO                  ;A/C TYPE T-37
720              SEIZE         P2                         ;CAPTURE THE AREA
730              DEPART        P2                         ;LEAVE THE QUEUE
740              JOIN          FARM                       ;JOIN THE GROUP
750              MARK          60                         ;COUNT THE TIME IN THE AREA
760              ADVANCE       2100,300                   ;DO SCHEDULED ACTIVITY
770              RELEASE       P2                         ;FREE THE AREA
780              REMOVE        FARM                       ;OUT OF THE GROUP
790 *
800              GATE FV       DANGE                      ;IF EMERGENCY ORBIT UNDER
810 TOIP         ADVANCE       120,30                     ;GOING TO EP1
820 IPE          QUEUE         CAP1                       ;ENTER THE QUEUE
830              SEIZE         DUMY1                      ;SYNCHRONIZE THE AIRCRAFTS
840              GATE FV       DANGE                      ;IF EMERGENCY ORBIT THERE
850              ENTER         CAP1                       ;CAPTURE THE STORAGE
860              TRANSFER      SIM,DIR,DLY
870 DLY          ADVANCE       10
880 DIR          DEPART        CAP1                       ;LEAVE THE QUEUE
890              RELEASE       DUMY1
900              ADVANCE       120,10                     ;GOING TOWARDS EP2
910              LEAVE         CAP1                       ;FREE THE STORAGE
920 *
930 BAK          QUEUE         CAP2                       ;ENTER THE QUEUE
940              SEIZE         DUMY2                      ;SYNCHRONIZE THE AIRCRAFTS
950              GATE FV       DANGE                      ;IF EMERGENCY ORBIT THERE
960              ENTER         CAP2                       ;ENTER THE STORAGE
970              TRANSFER      SIM,DRC,DLL
980 DLL          ADVANCE       10
990 DRC          DEPART        CAP2                       ;DEPART THE QUEUE
1000             RELEASE       DUMY2
1010             ADVANCE       70,10                      ;GOING TOWARDS IP
1020             LEAVE         CAP2                       ;FREE THE STORAGE
1030 *
1040 RWAY        QUEUE         CAP3                       ;ENTER THE QUEUE AT IP
1050             SEIZE         DUMY3                      ;SYNCHRONIZE THE AIRCRAFTS
1060             GATE FV       DANGE,EPI                  ;IF EMERGENCY GO TO EPI
1070             ENTER         CAP3                       ;ENTER THE STORAGE
1080             TRANSFER      SIM,DIREC,DELAY
1090 DELAY       ADVANCE       10
1100 DIREC       DEPART        CAP3                       ;DEPART THE QUEUE
1110             RELEASE       DUMY3
1120             ADVANCE       65,5                       ;GOING TOWARDS LIP
1130             LEAVE         CAP3                       ;FREE THE STORAGE
1140 *
1150 LIP         QUEUE         CAP4                       ;ENTER THE QUEUE AT LIP
1160             SEIZE         DUMY4                      ;SYNCHRONIZE THE AIRCRAFTS
1170             GATE FV       DANGE,EPI                  ;IF EMERGENCY GO TO EPI

1180             ENTER         CAP4                       ;ENTER THE STORAGE
```

```
1190          TRANSFER      SIM,DIRE,DELA
1200 DELA     ADVANCE       10
1210 DIRE     DEPART        CAP4                    ;LEAVE THE QUEUE
1220          RELEASE       DUMY4
1230          ADVANCE       70,10                   ;GOING TO BREAK POINT
1240          LEAVE         CAP4                    ;FREE THE STORAGE
1250          GATE FV       DANGE,EPI               ;IF EMERGENCY : GO TO ENTR.POINT
1260          GATE SNF      CAP5,CNTU               ;CHECK A/C ON DOWNWING DON'T QUEUE

1270 *
1280          ENTER         CAP5                    ;THEY ARE SYNCHRONIZED HERE
1290          ADVANCE       45,15                   ;DOWNWING LEG
1300          LEAVE         CAP5                    ;FREE THE STORAGE
1310          GATE FV       DANGE,FAST              ;IF EMERGENCY : GO TO ENTR.POINT
1320 BASE     GATE SNF      CAP6,GOAR               ;CHECK #A/C ON BASELEG DON'T QEUEU

1330          ENTER         CAP6                    ;ENTER THE CAPACITY
1340          ADVANCE       45,15                   ;BASE LEG
1350          LEAVE         CAP6                    ;FREE THE CAPACITY
1360 *
1370          GATE FV       DANGE,TELO              ;IF EMERGENCY DO FULL STOP
1380          GATE FV       CNTR,GOAR               ;IF A/C IN THE RUNWAY GO-AROUND
1390          TEST NE       P1,2,OUT                ;A/C FROM OTHER BASE
1400          TEST E        P1,1,TTT                ;CHECK FOR A/C TYPE T-37
1410          TEST LE       MP7,3900,TELO           ;CHECK FLIGHT TIME OF T-37
1430 MORE     ADVANCE       10,5                    ;TOUCH AND GO
1433          TEST NE       P1,2,CNTU
1436          SAVEVALUE     20+,1                   ;COUNT THE NUMBER OF LANDS
1440          TRANSFER      ,CNTU
1450 OUT      TEST G        MP4,900,MORE            ;CHECK FLIGHT TIME FOR FORR. A/C
1460 TELO     ADVANCE       20,5                    ;FULL STOP LANDING
1470          TEST NE       P1,2,PISTA              ;CHECK FOR OTHER TYPE A/C
1480 FINISH   TEST E        P1,1,TABULT2            ;IF A/C TYPE IS T-37 CONTINUE
1490          TABULATE      TOTAL37                 ;DISTRIBUTION OF THE TOTAL TIME
1500          TRANSFER      ,PISTA
1510 TABULT2 TABULATE       TOTALT2                 ;TABULATE T-2 FLIGHT TIME
1520 PISTA    TERMINATE
1530 *
1540 CNTU     ADVANCE       60,5                    ;CONTINUE TO LIP
1550          GATE FV       DANGE,CRIT              ;IF EMERGENCY : GO TO ENTR.POINT
1560 FST      TRANSFER      .20,,CLOSE              ;20% CONTINUE FOR CLOSE PATTERN
1570 HERE     GATE SNF      CAP3,EPI1               ;CHECK # A/C FROM IP TO LIP
1580 HERE1    TEST E        Q$CAP4,0,EPI            ;IF A/C WAITS AT LIP, GO TO EPI
1590          ADVANCE       120,20                  ;GOING TO LIP
1600          TRANSFER      ,LIP
1610 *
1620 EPI      ADVANCE       170,20                  ;GOING TO EP1
1630          TRANSFER      ,IPE
1640 *
1650 GOAR     ADVANCE       30,10                   ;GOING AROUND
1660          GATE SNE      CAP5,CLOSE              ;IF NO A/C IN DOWNWING DO CLOSE
1670          TRANSFER      ,HERE
1680 EPI1     TRANSFER      .30,HERE1,EPI           ;30% GO TO EPI
1690 *
1700 TTWO     SEIZE         P2                      ;CAPTURE THE AREA
1710          DEPART        P2                      ;LEAVE THE QUEUE
1720          JOIN          FARM                    ;JOIN THE GROUP
1730          MARK          60                      ;MARK THE TIME IN THE AREA
1740          ADVANCE       2400,300                ;DO THE SCHEDULED ACTIVITY
1750          RELEASE       P2                      ;FREE THE AREA
1760          REMOVE        FARM                    ;OUT OF THE GROUP
1770          TRANSFER      ,TOIP
1780 *
1790 *                    W E S T   A R E A S
1800 *
1810 WEST     SAVEVALUE     15+,P1                  ;RECORDS T-37'S
1820          SAVEVALUE     16+,1                   ;RECORDS TOTAL # A/C
1840          QUEUE         P2                      ;ENTER THE QUEUE

1850          TEST E        P1,1,TTWB               ;CHECK THE TYPE OF THE A/C
```

```
1860          SEIZE         P2                     ;A/C T-37 CAPTURES THE AREA
1870          DEPART        P2                     ;LEAVE THE QUEUE
1880          JOIN          FARM                   ;JOIN THE GROUP
1890          MARK          60                     ;MARK THE TIME IN THE AREA
1900          ADVANCE       2100,300               ;DO THE SCHEDULED ACTIVITY
1910          RELEASE       P2                     ;FREE THE AREA
1920          REMOVE        FARM                   ;OUT OF THE GROUP
1930          ADVANCE       200,100                ;GOING TO EP2
1940          TRANSFER      ,BAK
1950 *
1960 TTW3     SEIZE         P2                     ;A/C T-2 CAPTURES THE AREA
1970          DEPART        P2                     ;LEAVE THE QUEUE
1980          JOIN          FARM                   ;JOIN THE GROUP
1990          MARK          60                     ;MARK THE TIME IN THE AREA
2000          ADVANCE       2400,300               ;DO SCHEDULED ACTIVITY
2010          RELEASE       P2                     ;FREE THE AREA
2020          REMOVE        FARM                   ;OUT OF THE GROUP
2030          ADVANCE       200,100                ;GOING TO EP2
2040          TRANSFER      ,BAK
2050 *
2060 TTT      TEST LE       MP6,4500,TELO          ;CHECK FLIGHT TIME FOR T-2 A/C
2070          TRANSFER      ,MORE                  ;GO FOR FULL STOP
2080 *
2090 FAST     TRANSFER      .80,EPI,BASE           ;20% GO TO IPE, OTHERS CONTINUE
2100 CRIT     TRANSFER      .80,FST,EPI            ;80% GO TO IPE
2110 CLOSE    GATE FV       CNTR,HERE              ;IF NO A/C FOR TAKE OFF CONTINUE
2120          ADVANCE       45,15                  ;DOING CLOSE PATTERN
2130          TRANSFER      ,BASE                  ;BASE KEY
2140 *
2150 QUEUP    COUNT GE      13,101,108,1,Q         ;CHECK THE QUEUES IN ALL AREAS
2160            TEST L        P13,8,SLCT            ;CHECK IF ALL QUEUES ARE OCCUPIED

2170          SCAN MAX      FARM,MP60,,P2,2        ;FIND THE EARLIEST OCCUPIED AREA
2180          SAVEVALUE     32,P2
2190          REMOVE        FARM,ALL,,P2,X32,AREA   ;REMOVE FROM THE GROUP
2200          TRANSFER      ,AREA
2210 SLCT     SELECT MIN    2,101,108,,Q           ;SELECT AREA WITH THE MIN QUEUE
2220          SAVEVALUE     32,P2
2230          REMOVE        FARM,ALL,,P2,X32,AREA   ;REMOVE FROM THE GROUP
2240          TRANSFER      ,AREA
2243 OTHER    SAVEVALUE     30+,1                  ;A/C NOT GOING TO MISSION AREAS
2246          ADVANCE       2400,300               ;PERFORM SHEDULED ACTIVITIES
2248          TRANSFER      ,IPE                   ;BACK TO THE AIRPORT
2249 *
2250 *
2260 *                M A K E   T A B L E S
2270 *

2280 TOTAL37 TABLE          MP7,3600,240,18          ;TOTAL TIME DISTRIBUTION

2290 TOTALT2 TABLE          MP6,3600,240,18          ;TOTAL TIME DISTRIBUTION

2300 CNTR     QTABLE        CNTR,0,60,40             ;TIME DISTRIBUTION IN CNTR QUEUE

2310 CAP1     QTABLE        CAP1,0,30,40             ;TIME DISTRIBUTION IN CAP1 QUEUE

2320 CAP2     QTABLE        CAP2,0,30,40             ;TIME DISTRIBUTION IN CAP2 QUEUE

2330 CAP3     QTABLE        CAP3,0,30,40             ;TIME DISTRIBUTION IN CAP3 QUEUE

2340 CAP4     QTABLE        CAP4,0,30,40             ;TIME DISTRIBUTION IN CAP4 QUEUE

2350 AREA1     QTABLE         101,0,120,32            ;TIME DISTRIBUTION IN AREA Q101

2360 AREA2    QTABLE        102,0,120,32             ;TIME DISTRIBUTION  IN AREA Q102

2370 AREA3     QTABLE         103,0,120,32            ;TIME DISTRIBUTION IN AREA Q103

2380 AREA4    QTABLE        104,0,120,32             ;TIME DISTRIBUTION  IN AREA Q104
```

```
2390 AREA5   QTABLE      105,0,120,32          ;TIME DISTRIBUTION IN AREA Q105

2400 AREA6  QTABLE      106,0,120,32          ;TIME DISTRIBUTION  IN AREA Q106

2410 AREA7   QTABLE      107,0,120,32          ;TIME DISTRIBUTION IN AREA Q107

2420 AREA8  QTABLE      108,0,120,32          ;TIME DISTRIBUTION  IN AREA Q108

2430 *
2440 FIRST  BVARIABLE   (P2'E'101+P2'E'102+P2'E'103+P2'E'104)
2450 *
2460 *      D E F I N E  T H E  S T O R A G E S

2470 CAP1   STORAGE     2
2480 CAP2   STORAGE     2
2490 CAP3   STORAGE     2
2500 CAP4   STORAGE     3
2510 CAP5   STORAGE     3
2520 CAP6   STORAGE     2
2530 *

2540 *      T I M E  S E G M E N T

2550 GNRT   GENERATE    30600                 ;TIME ARRIVES AT 30600
2560        TEST E      N$DOWN,N$FINISH       ;WAIT UNTIL ALL THE A/C LAND
2570        TERMINATE   1                     ;SHUT OFF THE RUN
```

APPENDIX B

This appendix contains the GPSS program modifications for the different take off schedules.

SCHEDULE 1

```
10 ***********************************************************************
20 *                                                                     *
30 *                   AIR-TRAFFIC CONTROL  SIMULATION                   *
40 *                   -------------------------------                   *
50 *                                                                     *
60 ***********************************************************************
70 *
80 *
90 *                         EXPONENTIAL DISTRIBUTION
100 *
110 EXP      FUNCTION      RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN     FUNCTION      C1,D8
3600,390.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
170          GENERATE      ,,,1                     ;CREATE A SINGLE TRANSACTION
180 SWITCH1 LOGIC S        1                        ;SET LOGIC SWITCH 1
190          ADVANCE       300                      ;T-37 TAKE OFF
200          LOGIC R       1                        ;RESET LOGIC SWICH 1
210          ADVANCE       2100                     ;NONE T-37 TAKES OFF
220          TRANSFER      ,SWITCH1
230          GENERATE      ,,900,1
240 SWITCH2 LOGIC S        2                        ;SET LOGIC SWICH 2
250          ADVANCE       300                      ;T-2 TAKE OFF
260          LOGIC R       2                        ;RESET LOGIC SWICH 2
270          ADVANCE       2100                     ;NONE T-2 TAKES OFF
280          TRANSFER      ,SWITCH2
290          GENERATE      9000,FN$EXP              ;CREATE EMERGENCY EVENTS
300          SEIZE         DANGE
310          ADVANCE       600,180                  ;EMERGENCY HOLDS
320          RELEASE       DANGE
330          TERMINATE                              ;EMERGENCY TERMINATES
340 *
350          GENERATE      9100,FN$EXP              ;A/C FROM OTHER BASES
360          ASSIGN        1,2                      ;ASSIGN TO A PARAMETER
370          MARK          4                        ;MARK THE TIME
380          TRANSFER      ,EPI
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
420          GENERATE      60,10                    ;CREATE T-37'S
430          TEST L        N$GNRT,1,PISTA           ;THE SIMULATION STOPS AFTER
440          GATE LS       1,PISTA
450          ASSIGN        1,1                      ;ASSIGN TO A PARAMETER

460          TRANSFER      ,DOWN
470 *
480          GENERATE      60,10                    ;CREATE T-2'S
```

SCHEDULE 1A

```
10 *************************************************************************
20 *                                                                       *
30 *                   AIR-TRAFFIC CONTROL  SIMULATION                     *
40 *                   -------------------------------                     *
50 *                                                                       *
60 *************************************************************************
70 *
80 *
90 *                         EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION     RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION     C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
170         GENERATE     ,,,1                     ;CREATE A SINGLE TRANSACTION
180 SWITCH1 LOGIC S      1                        ;SET LOGIC SWITCH 1
190         ADVANCE      300                      ;T-37 TAKE OFF
200         LOGIC R      1                        ;RESET LOGIC SWICH 1
210         ADVANCE      2100                     ;NONE T-37 TAKES OFF
220         TRANSFER     ,SWITCH1
230         GENERATE     ,,900,1
240 SWITCH2 LOGIC S      2                        ;SET LOGIC SWICH 2
250         ADVANCE      300                      ;T-2 TAKE OFF
260         LOGIC R      2                        ;RESET LOGIC SWICH 2
270         ADVANCE      2100                     ;NONE T-2 TAKES OFF
280         TRANSFER     ,SWITCH2
290         GENERATE     9000,FN$EXP              ;CREATE EMERGENCY EVENTS
300         SEIZE        DANGE
310         ADVANCE      600,180                  ;EMERGENCY HOLDS
320         RELEASE      DANGE
330         TERMINATE                             ;EMERGENCY TERMINATES
340 *
350         GENERATE     9100,FN$EXP              ;A/C FROM OTHER BASES
360         ASSIGN       1,2                      ;ASSIGN TO A PARAMETER
370         MARK         4                        ;MARK THE TIME
380         TRANSFER     ,EPI
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
420         GENERATE     75,10                    ;CREATE T-37'S
430         TEST L       N$GNRT,1,PISTA           ;THE SIMULATION STOPS AFTER
440         GATE LS      1,PISTA
450         ASSIGN       1,1                      ;ASSIGN TO A PARAMETER

460         TRANSFER     ,DOWN
470 *
480         GENERATE     75,10                    ;CREATE T-2'S
490         TEST L       N$GNRT,1,PISTA

500         GATE LS      2,PISTA
510         ASSIGN       1,0                      ;ASSIGN TO A PARAMETER
520 DOWN    QUEUE        CNTR                     ;WAIT OUT OF THE RUNWAY
530         GATE FV      DANGE                    ;DONT MOVE IF EMERGENCY HOLDS
540 *       GATE SE      CAP6                     ;CHECK FOR A\C ON BASE LEG
```

SCHEDULE 1B

```
10 ************************************************************************
20 *                                                                      *
30 *                AIR-TRAFFIC CONTROL  SIMULATION                       *
40 *                -------------------------------                       *
50 *                                                                      *
60 ************************************************************************
70 *
80 *
90 *                    EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION      RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION      C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
170         GENERATE      ,,,1                ;CREATE A SINGLE TRANSACTION
180 SWITCH1 LOGIC S       1                   ;SET LOGIC SWITCH 1
190         ADVANCE       300                 ;T-37 TAKE OFF
200         LOGIC R       1                   ;RESET LOGIC SWICH 1
210         ADVANCE       3300                ;NONE T-37 TAKES OFF
220         TRANSFER      ,SWITCH1
230         GENERATE      ,,900,1
240 SWITCH2 LOGIC S       2                   ;SET LOGIC SWICH 2
250         ADVANCE       300                 ;T-2 TAKE OFF
260         LOGIC R       2                   ;RESET LOGIC SWICH 2
270         ADVANCE       3300                ;NONE T-2 TAKES OFF
280         TRANSFER      ,SWITCH2
290         GENERATE      9000,FN$EXP         ;CREATE EMERGENCY EVENTS
300         SEIZE         DANGE
310         ADVANCE       600,180             ;EMERGENCY HOLDS
320         RELEASE       DANGE
330         TERMINATE                         ;EMERGENCY TERMINATES
340 *
350         GENERATE      9100,FN$EXP         ;A/C FROM OTHER BASES
360         ASSIGN        1,2                 ;ASSIGN TO A PARAMETER
370         MARK          4                   ;MARK THE TIME
380         TRANSFER      ,EPI
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
420         GENERATE      60,10               ;CREATE T-37'S
430         TEST L        N$GNRT,1,PISTA      ;THE SIMULATION STOPS AFTER
440         GATE LS       1,PISTA
450         ASSIGN        1,1                 ;ASSIGN TO A PARAMETER

460         TRANSFER      ,DOWN
470 *
480         GENERATE      60,10               ;CREATE T-2'S
490         TEST L        N$GNRT,1,PISTA

500         GATE LS       2,PISTA
510         ASSIGN        1,0                 ;ASSIGN TO A PARAMETER
520 DOWN    QUEUE         CNTR                ;WAIT OUT OF THE RUNWAY
530         GATE FV       DANGE               ;DONT MOVE IF EMERGENCY HOLDS
540 *       GATE SE       CAP6                ;CHECK FOR A\C ON BASE LEG
```

SCHEDULE 2

```
10 ***********************************************************************
20 *                                                                     *
30 *                    AIR-TRAFFIC CONTROL  SIMULATION                  *
40 *                    ------------------------------                   *
50 *                                                                     *
60 ***********************************************************************
70 *
80 *
90 *                          EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION      RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION      C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
290             GENERATE      9000,FN$EXP          ;CREATE EMERGENCY EVENTS
300             SEIZE         DANGER
310             ADVANCE       600,180              ;EMERGENCY HOLDS
320             RELEASE       DANGER
330             TERMINATE                          ;EMERGENCY TERMINATES
340 *
350             GENERATE      9100,FN$EXP          ;A/C FROM OTHER BASES
360             ASSIGN        1,2                  ;ASSIGN TO A PARAMETER
370             MARK          4                    ;MARK THE TIME
380             TRANSFER      ,TOEP1
390 *
400 *    CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
411             GENERATE      120,10,,4            ;CREATE THE FIRST 4 T-37'S
412             ASSIGN        1,1                  ;ASSIGN TO A PARAMETER
413             TRANSFER      ,DOWN
414             GENERATE      120,10,60,4          ;CREATE THE FIRST 4 T-2'S
415             ASSIGN        1,0                  ;ASSIGN TO A PARAMETER
416             TRANSFER      ,DOWN
417 *
420             GENERATE      480,60,1500           ;CREATE T-37'S
430             TEST L        N$GNRT,1,PISTA        ;THE SIMULATION STOPS AFTER
431 *                                               ;ALL THE A/C HAVE LANDED
450             ASSIGN        1,1                   ;ASSIGN TO A PARAMETER
460             TRANSFER      ,DOWN
470 *
480             GENERATE      480,60,1740           ;CREATE T-2'S
490             TEST L        N$GNRT,1,PISTA        ;THE SIMULATION STOPS AFTER
491 *                                               ;ALL THE A/C HAVE LANDED
510             ASSIGN        1,0                   ;ASSIGN TO A PARAMETER
520 DOWN        QUEUE         CNTR                  ;WAIT OUT OF THE RUNWAY
530             GATE FV       DANGER                ;DONT MOVE IF EMERGENCY HOLDS
540             GATE SE       CAP6                  ;CHECK FOR A\C ON BASE LEG
550             SEIZE         CNTR                  ;CAPTURE THE CONTROLLER
560             DEPART        CNTR                  ;GOING FOR LINE UP
561 *
562 *                      L I N E  U P
570 LINEUP      ADVANCE       70,20                 ;LINE-UP CHECK
580             RELEASE       CNTR                  ;TAKE-OFF
590             MARK          6                     ;START FLIGHT TIMEFOR T-2 A/C
600             MARK          7                     ;START FLIGHT TIME FOR T-37 A/C
```

SCHEDULE 2A

```
10 *********************************************************************
20 *                                                                   *
30 *                 AIR-TRAFFIC CONTROL  SIMULATION                   *
40 *                 -------------------------------                   *
50 *                                                                   *
60 *********************************************************************
70 *
80 *
90 *                       EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION     RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION     C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
290         GENERATE     9000,FN$EXP         ;CREATE EMERGENCY EVENTS
300         SEIZE        DANGER
310         ADVANCE      600,180             ;EMERGENCY HOLDS
320         RELEASE      DANGER
330         TERMINATE                        ;EMERGENCY TERMINATES
340 *
350         GENERATE     9100,FN$EXP         ;A/C FROM OTHER BASES
360         ASSIGN       1,2                 ;ASSIGN TO A PARAMETER
370         MARK         4                   ;MARK THE TIME
380         TRANSFER     ,TOEP1
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
411         GENERATE     120,10,,4          ;CREATE THE FIRST 4 T-37'S
412         ASSIGN       1,1                ;ASSIGN TO A PARAMETER
413         TRANSFER     ,DOWN
414         GENERATE     120,10,60,4        ;CREATE THE FIRST 4 T-2'S
415         ASSIGN       1,0                ;ASSIGN TO A PARAMETER
416         TRANSFER     ,DOWN
417 *
420         GENERATE     600,60,1500         ;CREATE T-37'S
430         TEST L       N$GNRT,1,PISTA      ;THE SIMULATION STOPS AFTER
431 *                                        ;ALL THE A/C HAVE LANDED
450         ASSIGN       1,1                 ;ASSIGN TO A PARAMETER
460         TRANSFER     ,DOWN
470 *
480         GENERATE     600,60,1800         ;CREATE T-2'S
490         TEST L       N$GNRT,1,PISTA      ;THE SIMULATION STOPS AFTER
491 *                                        ;ALL THE A/C HAVE LANDED
510         ASSIGN       1,0                 ;ASSIGN TO A PARAMETER
520 DOWN    QUEUE        CNTR                ;WAIT OUT OF THE RUNWAY
530         GATE FV      DANGER              ;DONT MOVE IF EMERGENCY HOLDS
540         GATE SE      CAP6                ;CHECK FOR A\C ON BASE LEG
550         SEIZE        CNTR                ;CAPTURE THE CONTROLLER
560         DEPART       CNTR                ;GOING FOR LINE UP
561 *
562 *                 L I N E   U P
570 LINEUP  ADVANCE      70,20               ;LINE-UP CHECK
580         RELEASE      CNTR                ;TAKE-OFF
590         MARK         6                   ;START FLIGHT TIMEFOR T-2 A/C
600         MARK         7                   ;START FLIGHT TIME FOR T-37 A/C
```

SCHEDULE 3

```
10 ***********************************************************************
20 *                                                                     *
30 *                AIR-TRAFFIC CONTROL  SIMULATION                      *
40 *                -------------------------------                      *
50 *                                                                     *
60 ***********************************************************************
70 *
80 *
90 *                    EXPONENTIAL DISTRIBUTION
100 *
110 EXP     FUNCTION     RN1,C24
0,0/.1,.104/.2,.222/.3,.355/.4,.509/.5,.69/.6,.915/.7,1.2/.75,1.38
.8,1.6/.84,1.83/.88,2.12/.9,2.3/.92,2.52/.94,2.81/.95,2.99/.96,3.2
.97,3.5/.98,3.9/.99,4.6/.995,5.3/.998,6.2/.999,7/.9998,8
120 *
130 *
140 MEAN    FUNCTION     C1,D8
3600,380.11/5400,221.60/13200,488.62
15000,242.63/23400,557.83/25200,124.58
31800,494.60/36600,221.30
150 *
160 *
290         GENERATE     9000,FN$EXP          ;CREATE EMERGENCY EVENTS
300         SEIZE        DANGER
310         ADVANCE      600,180              ;EMERGENCY HOLDS
320         RELEASE      DANGER
330         TERMINATE                         ;EMERGENCY TERMINATES
340 *
350         GENERATE     9100,FN$EXP          ;A/C FROM OTHER BASES
360         ASSIGN       1,2                  ;ASSIGN TO A PARAMETER
370         MARK         4                    ;MARK THE TIME
380         TRANSFER     ,TOEP1
390 *
400 *   CREATE AIRCRAFTS FROM TWO DIFFERENT SQUADROMS ON BASE
410 *
420         GENERATE     FN$MEAN,FN$EXP       ;CREATE AIRCRAFT
430         TEST L       N$GNRT,1,PISTA       ;THE SIMULATION STOPS AFTER
435         TRANSFER     .49,,ACFTT2
450         ASSIGN       1,1                  ;ASSIGN TO A PARAMETER
460         TRANSFER     ,DOWN
470 *
510 ACFTT2  ASSIGN       1,0                  ;ASSIGN TO A PARAMETER
520 DOWN    QUEUE        CNTR                 ;WAIT OUT OF THE RUNWAY
530         GATE FV      DANGE                ;DONT MOVE IF EMERGENCY HOLDS
540         GATE SE      CAP6                 ;CHECK FOR A\C ON BASE LEG
550         SEIZE        CNTR                 ;CAPTURE THE CONTROLLER
560         DEPART       CNTR                 ;GOING FOR LINE UP
570 LINUP   ADVANCE      70,20                ;LINE-UP CHECK
580         RELEASE      CNTR                 ;TAKE-OFF
590         MARK         6                    ;START FLIGHT TIMEFOR T-2 A/C
600         MARK         7                    ;START FLIGHT TIME FOR T-37 A/C
610         ADVANCE      100,10               ;AFTER TAKE OFF TO DEPART POINT
615         TRANSFER     .25,,OTHER           ;FORMATIONS, INSTR.FL., CPM
620 *
630         SELECT E     2,101,108,0,F,QUEUP  ;FIND EMPTY AREA IF EXISTS ONE
640 AREA    TEST E       BV$FIRST,1,WEST      ;CHOOSE EAST OR WEST AREA
650 *
660 *     E A S T   A R E A S
670 *
680         SAVEVALUE    13+,P1               ;RECORDS T-37'S
690         SAVEVALUE    14+,1                ;RECORDS TOTAL # OF A/C
700 WAIT    QUEUE        P2                   ;WAIT IN THE QUEUE
```

APPENDIX C

This appendix contains the historical data for a three day period. For each aircraft the historical data consisted of the interarrival times for take off, the time spent waiting in the air traffic controller queue, the time spent waiting to ente area 3 and the total flight time of T-37 aircraft. All times are stated in seconds.

Interarrival times for take off

```
     INARRDAY1  (Interarrival Times for take off Day 1)
557 218 254 399 968 48 16 91 211 490 484 622 43 11 7 541 41 171 160 177 191 435
     472 82 27 646 305 1410 154 490 196 479 358 1637 207 84 568 548 1211 511
     31 225 85 565 41 149 778 279 157 362 575 1147 305 288 475 383 635 118 844
     274 1623 117 173 6 31 58 24 57 183 775 92 7 142 260 7 481 77 260 587 77
     39 378 225 235 786 70 183 200 79 322 22 59 118 298 70 3 280 146
```

```
     INARRDAY2  (Interarrival Times for take off Day 2)
291 228 259 597 89 70 351 1415 147 179 1006 388 167 43 478 22 135 18 21 357 257
     606 207 413 17 260 959 414 182 1424 486 33 213 304 1188 362 261 177 211
     91 53 310 14 128 267 304 90 37 274 11 804 959 580 425 1491 280 887 6 235
     947 114 155 141 157 46 63 152 155 151 113 128 37 1101 1142 919 242 132
     1460 216 397 61 1029 393 26 221 80 52 534 85 99 261 382 60 112
```

```
     INARRDAY3  (Interarrival Times for take off Day 3)
438 170 1353 577 124 144 88 338 260 636 330 27 547 15 427 52 127 42 267 23 11
     94 323 141 576 115 798 421 148 171 657 214 20 371 106 1356 78 120 22 51
     114 64 922 1135 481 1832 665 296 45 34 519 230 204 14 102 708 1238 1134
     1027 570 564 916 221 49 333 7 168 87 91 2 504 252 35 62 39 55 144 165 67
     107 2 116 146 357 270 980 1422 869 334 1097 873 277 447 312 621 274 30 21
     492 71 452 530 741 143 676
```

Time spent waiting in the air traffic controller queue

Waiting Time	Controller queue			Area 3		
	day1	day2	day3	day1	day2	day3
0	42	45	49	14	12	13
60	42	38	31	0	0	1
120	12	20	11	1	1	0
180	3	5	4	0	1	0
240	2	2	0	0	0	1
300	0	0	0	0	1	0
420	0	2	0	0	0	0
480	0	0	0	0	0	1
540	0	0	1	0	0	0
660	0	0	0	1	0	0
720	0	0	0	1	0	0
840	0	0	0	0	0	1
960	0	0	0	1	0	0
1020	0	0	0	0	1	0

Total flight time aircraft T-37

Time	day1	day2	day3
3960	6	5	8
4080	23	18	13
4200	12	23	17
4320	10	9	8
4440	4	3	2
4560	0	2	1
4800	0	1	0

APPENDIX D

This appendix contains the summary statistics and the hypothesis test results for the eight time periods for which the interarrival times for take off were homogeneous. These times periods were:

1) 07:30 - 08:40
2) 08:40 - 09:10
3) 09:10 - 11:10
4) 11:10 - 11:40
5) 11:40 - 14:00
6) 14:00 - 14:30
7) 14:30 - 16:20
8) 16:20 - 17:30

The Tables D.1 and D.2 contain the summary statistics for each time period and the figures D.1 through D.8 contain the distribution fitting and the Kolmogorov-Smirnov test results.

Table D.1 Summary Statistics

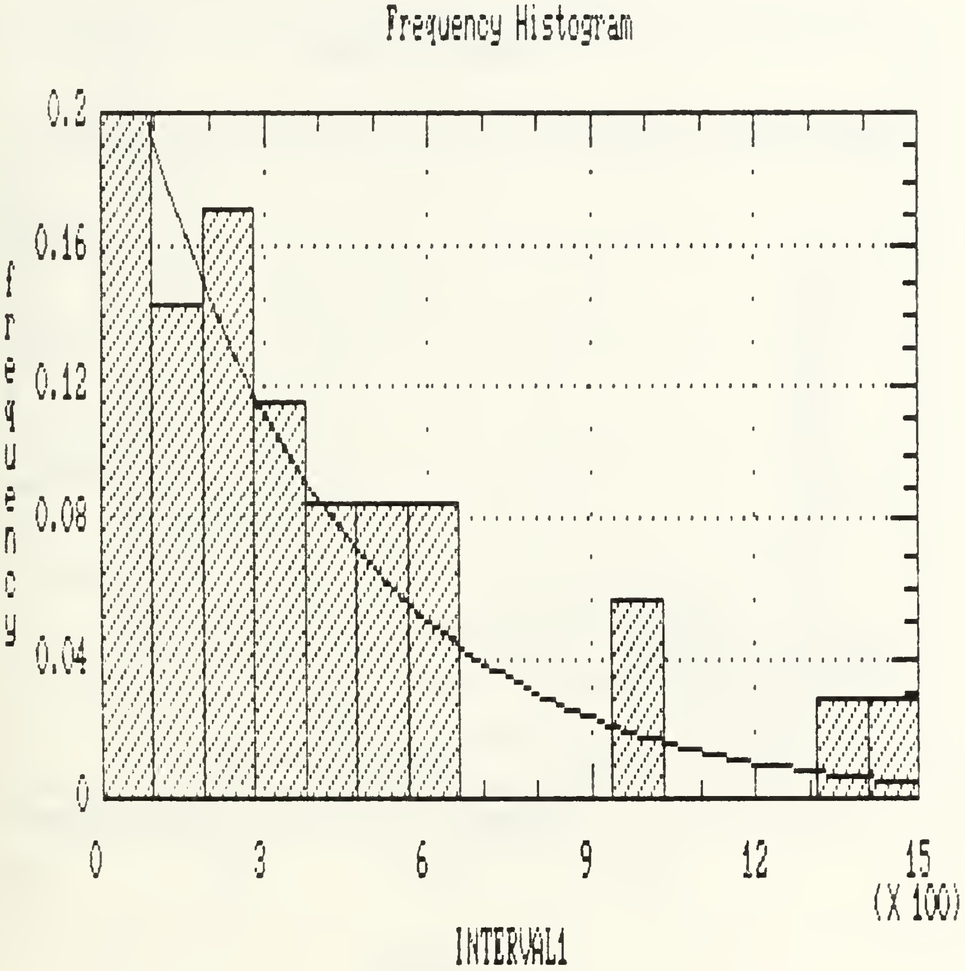
Variable:	INTERVAL1	INTERVAL2
Sample size	35	45
Average	380.114	221.689
Median	260	160
Mode	259	11
Geometric mean	248.624	116.221
Variance	120438	44135.7
Standard deviation	347.041	210.085
Standard error	58.6607	31.3176
Minimum	16	7
Maximum	1415	798
Range	1399	791
Lower quartile	144	42
Upper quartile	547	413
Interquartile range	403	371
Skewness	1.65105	0.928257
Standardized skewness	3.98766	2.54214
Kurtosis	2.56701	-0.118849
Standardized kurtosis	3.09996	-0.162741

Variable:	INTERVAL3	INTERVAL4
Sample size	47	27
Average	488.617	242.63
Median	305	204
Mode	304	14
Geometric mean	284.774	144.641
Variance	229164	49612.2
Standard deviation	478.711	222.738
Standard error	69.8271	42.866
Minimum	20	14
Maximum	1832	778
Range	1812	764
Lower quartile	120	45
Upper quartile	646	304
Interquartile range	526	259
Skewness	1.28888	1.1451
Standardized skewness	3.60734	2.42911
Kurtosis	0.696499	0.434659
Standardized kurtosis	0.974683	0.461025

Table D.2 Summary Statistics

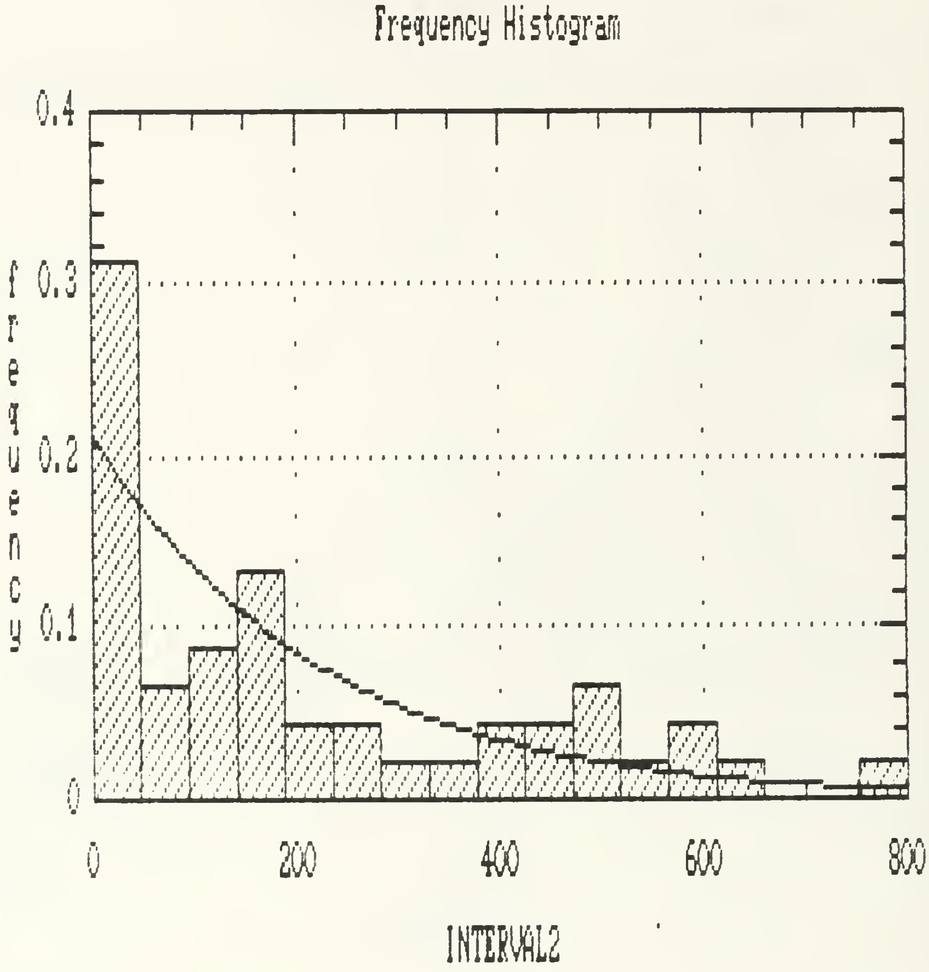
```
Variable:                     INTERVAL5          INTERVAL6
==============================================================
Sample size                     36                  39
Average                         557.833             124.897
Median                          450                 107
Mode                            383                 2
Geometric mean                  322.289             69.1587
Variance                       190050             20045.8
Standard deviation              435.947             141.583
Standard error                  72.6579             22.6714
Minimum                         6                   2
Maximum                         1623                775
Range                           1617                773
Lower quartile                  228                 39
Upper quartile                  901.5               155
Interquartile range             673.5               116
Skewness                          0.705837            3.12258
Standardized skewness             1.72894             7.96105
Kurtosis                         -0.301508           12.1983
Standardized kurtosis            -0.36927            15.5498
==============================================================


Variable:                     INTERVAL7          INTERVAL8
==============================================================
Sample size                     38                  30
Average                         494.605             221.3
Median                          345.5               130.5
Mode                            77                  112
Geometric mean                  327.136             129.011
Variance                       165600              42845
Standard deviation              406.94              206.99
Standard error                  66.0143             37.7911
Minimum                         26                  3
Maximum                         1460                741
Range                           1434                738
Lower quartile                  216                 70
Upper quartile                  869                 322
Interquartile range             653                 252
Skewness                          0.90161             1.10583
Standardized skewness             2.269               2.4727
Kurtosis                         -0.289484            0.246429
Standardized kurtosis            -0.364259            0.275516
==============================================================
```



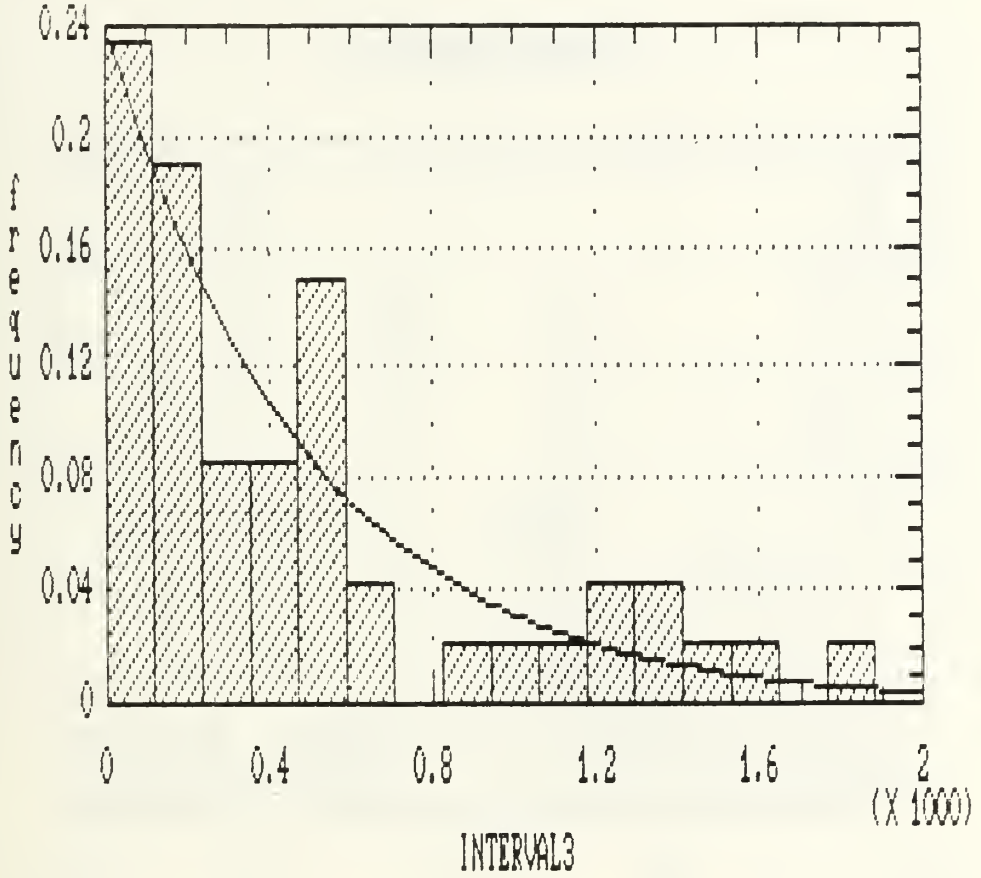
```
Estimated KOLMOGOROV statistic DPLUS = 0.0733633
Estimated KOLMOGOROV statistic DMINUS = 0.0923791
Estimated overall statistic DN = 0.0923791
Approximate significance level = 1
```

Figure D.1 Distribution Fitting Interval 1



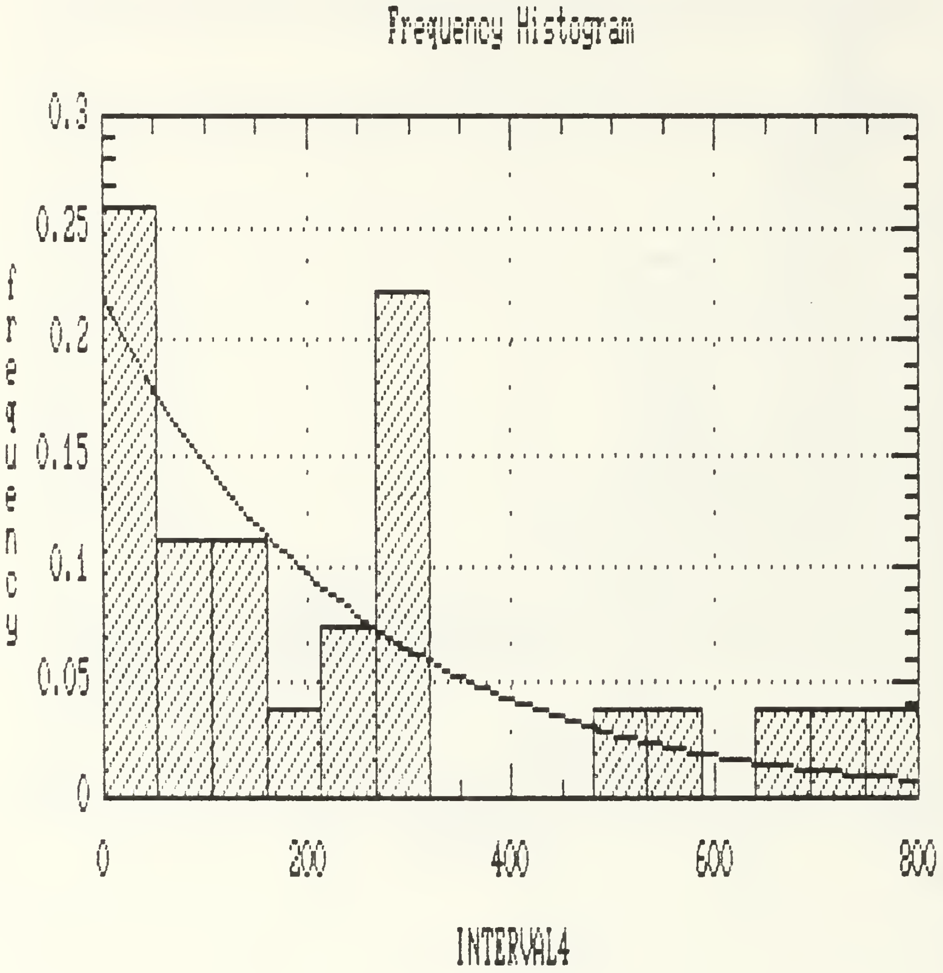
```
Estimated KOLMOGOROV statistic DPLUS = 0.134797
Estimated KOLMOGOROV statistic DMINUS = 0.111456
Estimated overall statistic DN = 0.134797
Approximate significance level = 0.386891
```

Figure D.2 Distribution Fitting Interval 2



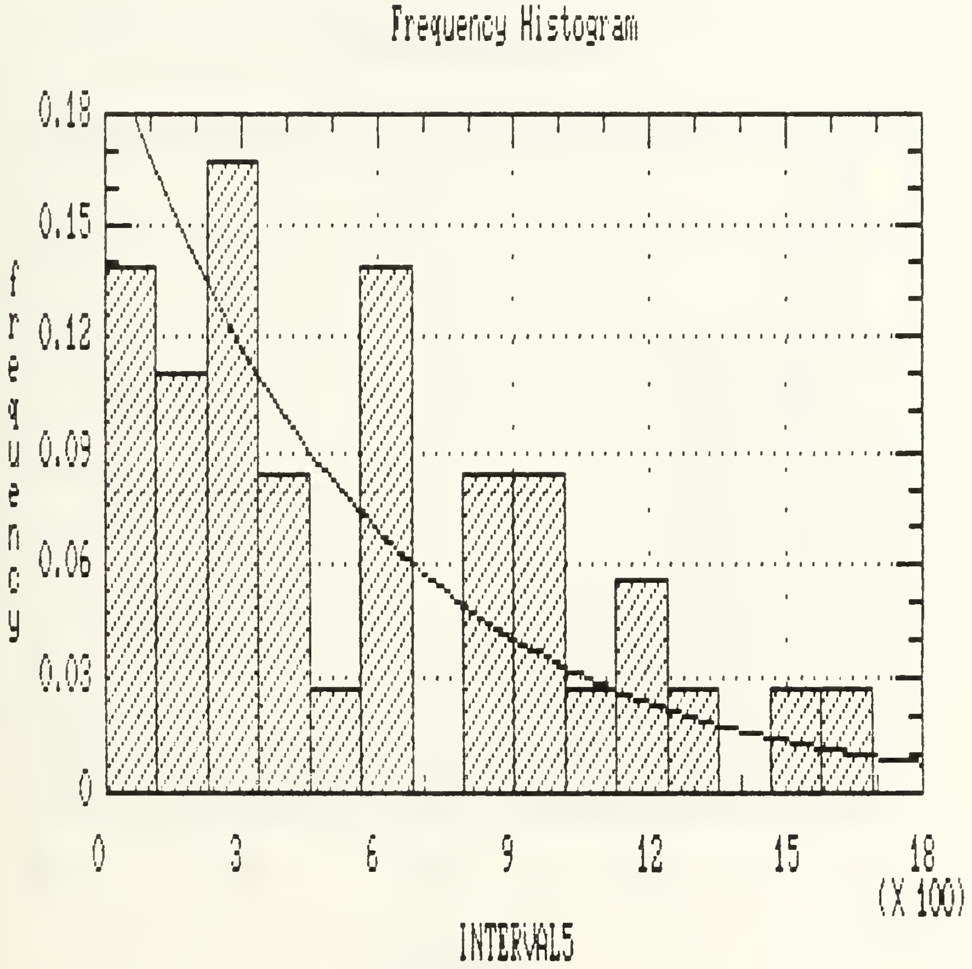
```
Estimated KOLMOGOROV statistic DPLUS = 0.0708765
Estimated KOLMOGOROV statistic DMINUS = 0.0722221
Estimated overall statistic DN = 0.0722221
Approximate significance level = 1
```

Figure D.3 Distribution Fitting Interval 3



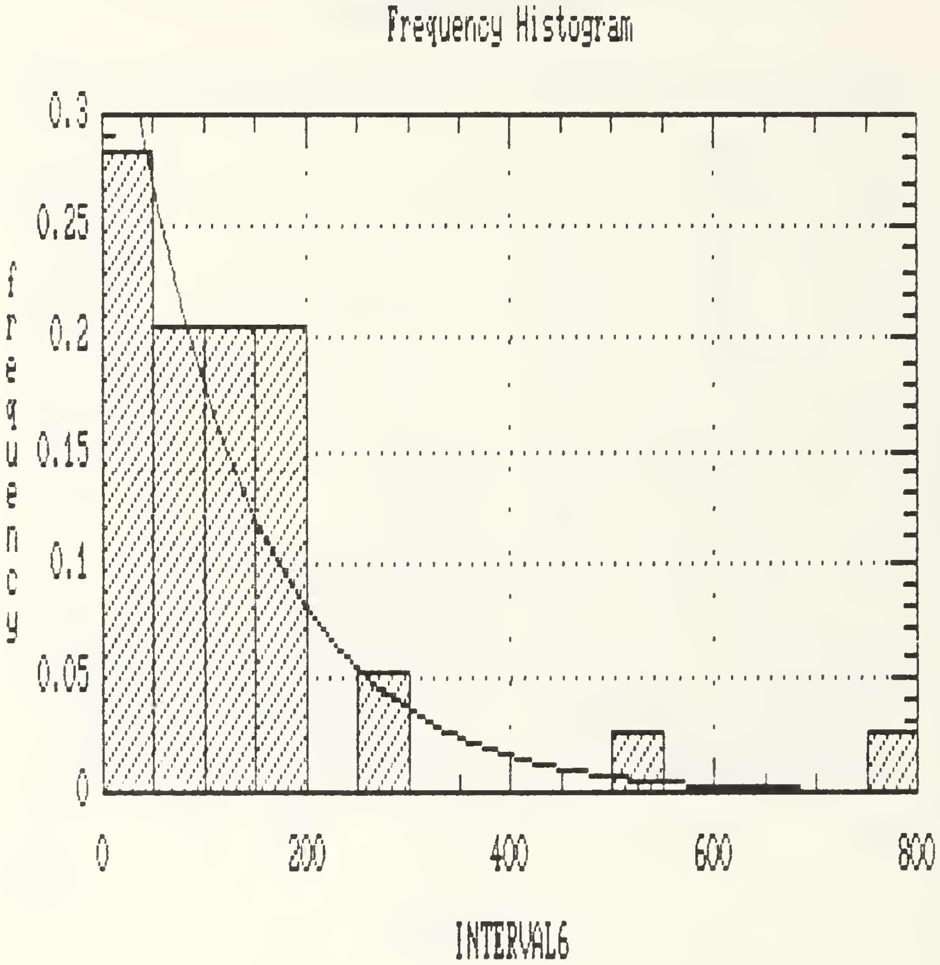
```
Estimated KOLMOGOROV statistic DPLUS = 0.0935019
Estimated KOLMOGOROV statistic DMINUS = 0.0871474
Estimated overall statistic DN = 0.0935019
Approximate significance level = 1
```

Figure D.4 Distribution Fitting Interval 4



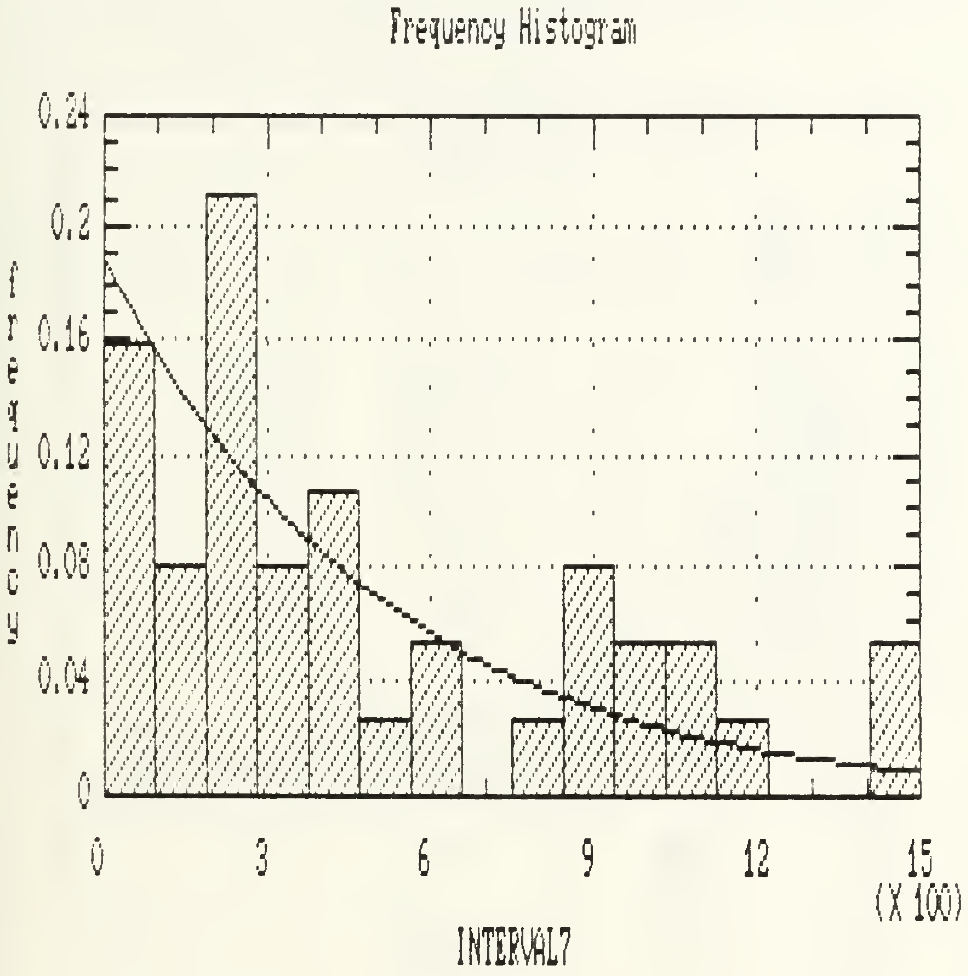
```
Estimated KOLMOGOROV statistic DPLUS = 0.0638073
Estimated KOLMOGOROV statistic DMINUS = 0.110322
Estimated overall statistic DN = 0.110322
Approximate significance level = 0.999951
```

Figure D.5 Distribution Fitting Interval 5



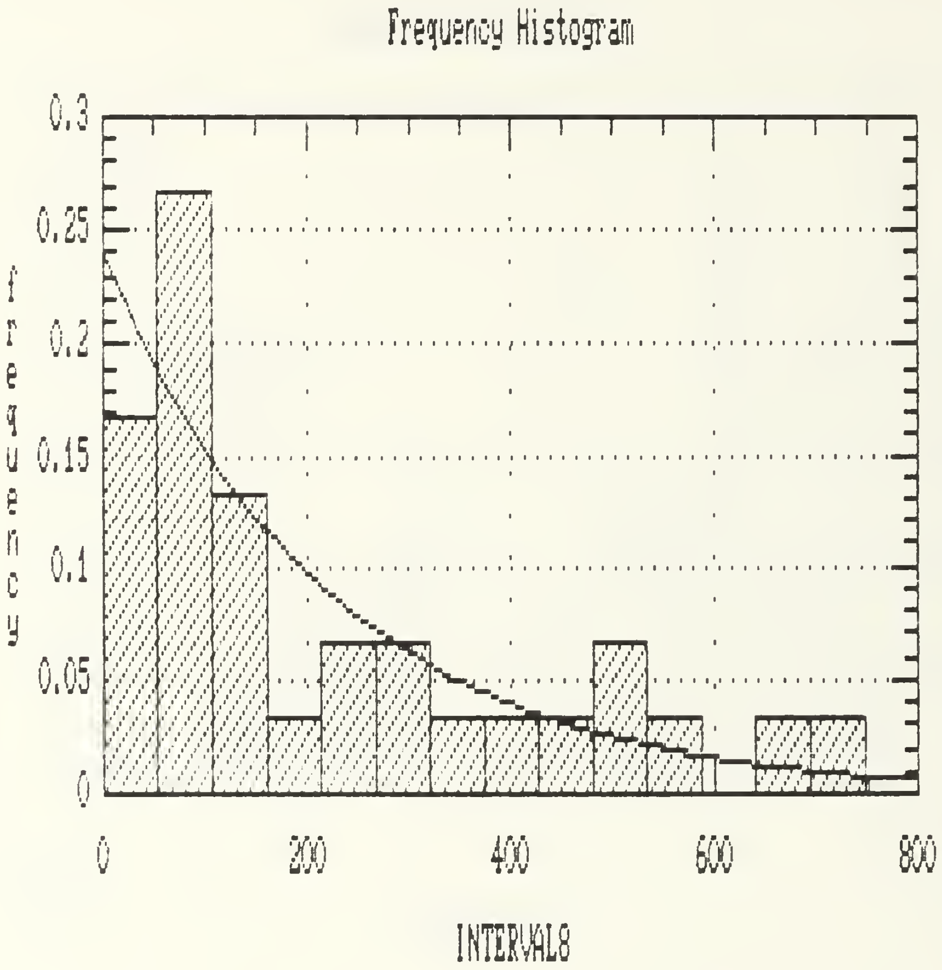
```
Estimated KOLMOGOROV statistic DPLUS = 0.128466
Estimated KOLMOGOROV statistic DMINUS = 0.0882622
Estimated overall statistic DN = 0.128466
Approximate significance level = 0.540454
```

Figure D.6 Distribution Fitting Interval 6



```
Estimated KOLMOGOROV statistic DPLUS = 0.0533982
Estimated KOLMOGOROV statistic DMINUS = 0.117
Estimated overall statistic DN = 0.117
Approximate significance level = 0.999736
```

Figure D.7 Distribution Fitting Interval 7



```
Estimated KOLMOGOROV statistic DPLUS = 0.0867169
Estimated KOLMOGOROV statistic DMINUS = 0.0760762
Estimated overall statistic DN = 0.0867169
Approximate significance level = 1
```

Figure D.8 Distribution Fitting Interval 8

APPENDIX E

This appendix contains the GPSS program outputs for each take off schedule.

SCHEDULE 1

```
FACILITY     ENTRIES  UTIL.    AVE. TIME AVAILABLE  OWNER PEND  INTER RETRY DELAY

  101            14   0.877    2180.86       1          0    0      0      0     0
  102            14   0.850    2113.79       1          0    0      0      0     0
  103            12   0.747    2168.25       1          0    0      0      0     0
  104            12   0.831    2412.67       1          0    0      0      0     0
  105            11   0.694    2195.82       1          0    0      0      0     0
  106            12   0.808    2345.33       1          0    0      0      0     0
  107            12   0.799    2317.33       1          0    0      0      0     0
  108             9   0.594    2300.00       1          0    0      0      0     0
 DANGE            2   0.041     728.00       1          0    0      0      0     0
 CNTR           130   0.266      71.36       1          0    0      0      0     0
 DUMY1          116   0.011       3.35       1          0    0      0      0     0
 DUMY2          160   0.000       0.10       1          0    0      0      0     0
 DUMY3          160   0.000       0.00       1          0    0      0      0     0
 DUMY4          624   0.047       2.67       1          0    0      0      0     0
```

```
QUEUE          MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY

  101            1     0      14        11      0.10     255.07   1190.33    0
  102            1     0      14        13      0.03      71.43   1000.00    0
  103            1     0      12        11      0.01      29.92    359.00    0
  104            1     0      12         7      0.04     109.50    262.80    0
  105            1     0      11         9      0.02      53.00    291.50    0
  106            1     0      12         7      0.01      41.92    100.60    0
  107            1     0      12         7      0.05     155.25    372.60    0
  108            1     0       9         5      0.04     157.44    354.25    0
 CNTR            2     0     130        33      0.09      24.61     32.98    0
 CAP1            2     0     116       109      0.01       3.82     63.29    0
 CAP2            1     0     160       159      0.00       0.10     16.00    0
 CAP3            1     0     160       160      0.00       0.00      0.00    0
 CAP4            3     0     624       557      0.06       3.11     28.94    0
```

```
STORAGE          CAP. REMAIN. MIN.   MAX.   ENTRIES AVL.   AVE.C.  UTIL.  RETRY DELAY

 CAP1               2      2     0      2       116    1    0.40   0.201    0     0
 CAP2               2      2     0      2       160    1    0.32   0.161    0     0
 CAP3               2      2     0      2       160    1    0.30   0.150    0     0
 CAP4               3      3     0      3       624    1    1.28   0.425    0     0
 CAP5               3      3     0      3       624    1    0.81   0.269    0     0
 CAP6               2      2     0      2       648    1    0.84   0.418    0     0
```

```
TABLE             MEAN      STD.DEV. RETRY  RANGE              FREQUENCY  CUM. %
 CNTR             24.61      22.11     0
                                          -        0              33       25.38
                                        0 -       60              87       92.31
                                       60 -      120              10      100.00

 CAP1              3.82      17.01     0
                                          -        0             109       93.97
                                       30 -       60               4       97.41
                                       60 -       90               1       98.28
                                       90 -      120               1       99.14
                                      120 -      150               1      100.00

 CAP2              0.10       1.26     0
                                          -        0             159       99.37
                                        0 -       30               1      100.00

 CAP3              0.00       0.00     0
                                          -        0             160      100.00

 CAP4              3.11       9.92     0
                                          -        0             557       89.26
                                        0 -       30              38       95.35
                                       30 -       60              29      100.00

 TOTAL37        4159.52     164.86     0
                                     3840 -     4080              26       39.39
                                     4080 -     4320              31       86.36
                                     4320 -     4560               6       95.45
                                     4560 -     4800               3      100.00

 TOTALT2        4750.58     138.22     0
                                     4320 -     4560               4        6.25
                                     4560 -     4800              36       62.50
                                     4800 -     5040              21       95.31
                                     5040 -     5280               3      100.00


TABLE             MEAN      STD.DEV. RETRY  RANGE              FREQUENCY  CUM. %
 AREA1           255.07     510.60     0
                                          -        0              11       78.57
                                      960 -     1080               1       85.71
                                     1200 -     1320               1       92.86
                                     1320 -     1440               1      100.00

 AREA2            71.43     267.26     0
                                          -        0              13       92.86
                                      960 -     1080               1      100.00

 AREA3            29.92     103.63     0
                                          -        0              11       91.67
                                      240 -      360               1      100.00

 AREA4           109.50     181.31     0
                                          -        0               7       58.33
                                        0 -      120               2       75.00
                                      240 -      360               1       83.33
                                      360 -      480               2      100.00

 AREA5            53.00     138.98     0
                                          -        0               9       81.82
                                      120 -      240               1       90.91
                                      360 -      480               1      100.00
```

```
TABLE              MEAN       STD.DEV.  RETRY  RANGE              FREQUENCY   CUM. %
 AREA6             41.92       63.52     0
                                               -          0            7       58.33
                                             0 -        120            3       83.33
                                           120 -        240            2      100.00

 AREA7            155.25      228.73     0
                                               -          0            7       58.33
                                             0 -        120            1       66.67
                                           240 -        360            2       83.33
                                           360 -        480            1       91.67
                                           600 -        720            1      100.00

 AREA8            157.44      283.67     0
                                               -          0            5       55.56
                                             0 -        120            1       66.67
                                           120 -        240            2       88.89
                                           840 -        960            1      100.00
```

SCHEDULE 1A

```
FACILITY      ENTRIES  UTIL.    AVE. TIME AVAILABLE  OWNER PEND INTER  RETRY DELAY

  101              13  0.775     2066.31      1          0    0     0      0     0
  102              13  0.792     2111.69      1          0    0     0      0     0
  103              11  0.740     2330.18      1          0    0     0      0     0
  104              11  0.735     2316.09      1          0    0     0      0     0
  105               9  0.600     2311.22      1          0    0     0      0     0
  106               9  0.607     2338.22      1          0    0     0      0     0
  107               6  0.417     2410.33      1          0    0     0      0     0
  108               6  0.395     2281.83      1          0    0     0      0     0
 DANGE              1  0.022      772.00      1          0    0     0      0     0
 CNTR             106  0.208       67.97      1          0    0     0      0     0
 DUMY1             93  0.011        4.33      1          0    0     0      0     0
 DUMY2            123  0.000        0.11      1          0    0     0      0     0
 DUMY3            123  0.000        0.12      1          0    0     0      0     0
 DUMY4            522  0.019        1.28      1          0    0     0      0     0



QUEUE             MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME  AVE.(-0) RETRY

  101               1    0      13        13       0.00      0.00      0.00     0
  102               1    0      13        13       0.00      0.00      0.00     0
  103               1    0      11        10       0.00      3.45     38.00     0
  104               1    0      11        10       0.00      0.18      2.00     0
  105               1    0       9         9       0.00      0.00      0.00     0
  106               1    0       9         8       0.01     26.56    239.00     0
  107               1    0       6         6       0.00      0.00      0.00     0
  108               1    0       6         5       0.00     13.00     78.00     0
 CNTR               1    0     106        78       0.01      2.72     10.29     0
 CAP1               2    0      93        87       0.01      4.71     73.00     0
 CAP2               1    0     123       122       0.00      0.11     14.00     0
 CAP3               1    0     123       122       0.00      0.12     15.00     0
 CAP4               2    0     522       494       0.02      1.33     24.82     0


STORAGE           CAP. REMAIN. MIN.   MAX.   ENTRIES AVL.   AVE.C.  UTIL. RETRY DELAY

 CAP1               2      2     0      2        93    1     0.32  0.162    0     0
 CAP2               2      2     0      2       123    1     0.25  0.123    0     0
 CAP3               2      2     0      2       123    1     0.23  0.116    0     0
 CAP4               3      3     0      3       522    1     1.06  0.355    0     0
 CAP5               3      3     0      3       522    1     0.67  0.225    0     0
 CAP6               2      2     0      2       572    1     0.74  0.372    0     0


TABLE             MEAN      STD.DEV. RETRY  RANGE             FREQUENCY   CUM. %

 CNTR              2.72        5.60    0
                                         -           0          78       73.58
                                      0  -          60          28      100.00

 CAP1              4.71       18.51    0
                                         -           0          87       93.55
                                     30  -          60           2       95.70
                                     60  -          90           3       98.92
                                     90  -         120           1      100.00
```

```
TABLE           MEAN      STD.DEV.  RETRY  RANGE           FREQUENCY  CUM. %
 CAP2           0.11         1.26    0
                                          -          0        122      99.19
                                     0  -           30          1     100.00

 CAP3           0.12         1.35    0
                                          -          0        122      99.19
                                     0  -           30          1     100.00

 CAP4           1.33         6.27    0
                                          -          0        494      94.64
                                     0  -           30         19      98.28
                                    30  -           60          9     100.00

 TOTAL37     4128.00       136.31    0
                                  3840  -         4080         25      48.08
                                  4080  -         4320         22      90.38
                                  4320  -         4560          5     100.00

 TOTALT2     4703.52       128.07    0
                                  4320  -         4560          6      11.11
                                  4560  -         4800         37      79.63
                                  4800  -         5040          9      96.30
                                  5040  -         5280          2     100.00
```

```
TABLE           MEAN      STD.DEV.  RETRY  RANGE           FREQUENCY  CUM. %
AREA1           0.00         0.00    0
                                          -          0         13     100.00

AREA2           0.00         0.00    0
                                          -          0         13     100.00

AREA3           3.45        11.46    0
                                          -          0         10      90.91
                                     0  -          120          1     100.00

AREA4           0.18         0.60    0
                                          -          0         10      90.91
                                     0  -          120          1     100.00

AREA5           0.00         0.00    0
                                          -          0          9     100.00

AREA6          26.56        79.67    0
                                          -          0          8      88.89
                                   120  -          240          1     100.00

AREA7           0.00         0.00    0
                                          -          0          6     100.00

AREA8          13.00        31.84    0
                                          -          0          5      83.33
                                     0  -          120          1     100.00
```

SCHEDULE 1B

```
FACILITY      ENTRIES  UTIL.    AVE. TIME AVAILABLE  OWNER PEND  INTER RETRY DELAY

   101            12  0.774     2250.17     1          0     0      0     0     0
   102            10  0.626     2182.40     1          0     0      0     0     0
   103             9  0.528     2045.89     1          0     0      0     0     0
   104             9  0.549     2127.67     1          0     0      0     0     0
   105             9  0.578     2238.22     1          0     0      0     0     0
   106             9  0.619     2399.67     1          0     0      0     0     0
   107             9  0.637     2466.11     1          0     0      0     0     0
   108             8  0.541     2357.25     1          0     0      0     0     0
  DANGE            6  0.097      568.50     1          0     0      0     0     0
  CNTR            89  0.182       71.39     1          0     0      0     0     0
  DUMY1           63  0.014        8.25     1          0     0      0     0     0
  DUMY2           98  0.002        0.92     1          0     0      0     0     0
  DUMY3           98  0.000        0.00     1          0     0      0     0     0
  DUMY4          423  0.009        0.81     1          0     0      0     0     0



QUEUE          MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME    AVE.(-0) RETRY

   101           1     0      12          8      0.09     251.83      755.50    0
   102           1     0      10          9      0.03     108.80     1088.00    0
   103           1     0       9          9      0.00       0.00        0.00    0
   104           1     0       9          9      0.00       0.00        0.00    0
   105           1     0       9          9      0.00       0.00        0.00    0
   106           1     0       9          9      0.00       0.00        0.00    0
   107           1     0       9          9      0.00       0.00        0.00    0
   108           1     0       8          8      0.00       0.00        0.00    0
  CNTR           2     0      89         24      0.07      25.52       34.94    0
  CAP1           2     0      63         54      0.02       9.57       67.00    0
  CAP2           1     0      98         96      0.00       0.92       45.00    0
  CAP3           1     0      98         98      0.00       0.00        0.00    0
  CAP4           2     0     423        410      0.01       0.85       27.62    0



STORAGE          CAP. REMAIN. MIN.  MAX.  ENTRIES AVL.  AVE.C. UTIL.  RETRY DELAY

  CAP1             2     2     0     2       63    1    0.22  0.110    0     0
  CAP2             2     2     0     2       98    1    0.20  0.099    0     0
  CAP3             2     2     0     2       98    1    0.18  0.092    0     0
  CAP4             3     3     0     3      423    1    0.86  0.286    0     0
  CAP5             3     3     0     3      423    1    0.55  0.184    0     0
  CAP6             2     2     0     2      481    1    0.62  0.308    0     0
```

```
TABLE            MEAN      STD.DEV.  RETRY  RANGE           FREQUENCY  CUM. %
 CNTP            25.52       25.71    0
                                            -        0          24      26.97
                                          0 -       60          53      86.52
                                         60 -      120          12     100.00

 CAP1             9.57       25.53    0
                                            -        0          54      85.71
                                         30 -       60           5      93.65
                                         60 -       90           2      96.83
                                         90 -      120           2     100.00

 CAP2             0.92        7.87    0
                                            -        0          96      97.96
                                          0 -       30           1      98.98
                                         60 -       90           1     100.00

 CAP3             0.00        0.00    0
                                            -        0          98     100.00

 CAP4             0.85        5.24    0
                                            -        0         410      96.93
                                          0 -       30           8      98.82
                                         30 -       60           5     100.00
TABLE            MEAN      STD.DEV.  RETRY  RANGE           FREQUENCY  CUM. %
 TOTAL37       4113.14      168.38    0
                                       3840 -     4080          23      52.27
                                       4080 -     4320          18      93.18
                                       4320 -     4560           2      97.73
                                       4560 -     4800           1     100.00

 TOTALT2       4680.07      103.17    0
                                       4320 -     4560           4       8.89
                                       4560 -     4800          32      80.00
                                       4800 -     5040           9     100.00


TABLE            MEAN      STD.DEV.  RETRY  RANGE           FREQUENCY  CUM. %
 AREA1          251.83      465.20    0
                                            -        0           8      66.67
                                          0 -      120           1      75.00
                                        600 -      720           1      83.33
                                       1080 -     1200           2     100.00

 AREA2          108.80      344.06    0
                                            -        0           9      90.00
                                       1080 -     1200           1     100.00

 AREA3            0.00        0.00    0
                                            -        0           9     100.00

 AREA4            0.00        0.00    0
                                            -        0           9     100.00

 AREA5            0.00        0.00    0
                                            -        0           9     100.00

 AREA6            0.00        0.00    0
                                            -        0           9     100.00

 AREA7            0.00        0.00    0
                                            -        0           9     100.00
 AREA8            0.00        0.00    0
                                            -        0           8     100.00
```

SCHEDULE 2

```
FACILITY     ENTRIES  UTIL.    AVE. TIME AVAILABLE  OWNER PEND  INTER   RETRY DELAY

  101            12  0.805     2382.08        1          0     0      0       0     0
  102            13  0.819     2238.15        1          0     0      0       0     0
  103            13  0.759     2073.38        1          0     0      0       0     0
  104            12  0.757     2239.42        1          0     0      0       0     0
  105            11  0.739     2387.18        1          0     0      0       0     0
  106            11  0.730     2356.36        1          0     0      0       0     0
  107             9  0.584     2303.89        1          0     0      0       0     0
  108             8  0.517     2298.12        1          0     0      0       0     0
 DANGE            4  0.071      637.25        1          0     0      0       0     0
 CNTR           130  0.261       71.32        1          0     0      0       0     0
 DUMY1          111  0.006        2.21        1          0     0      0       0     0
 DUMY2          150  0.000        0.08        1          0     0      0       0     0
 DUMY3          150  0.000        0.00        1          0     0      0       0     0
 DUMY4          622  0.033        1.91        1          0     0      0       0     0
```

```
QUEUE          MAX   CONT.  ENTRIES ENTRIES(O) AVE.CONT.  AVE.TIME   AVE.(-0)  RETRY

  101           1      0       12         8      0.03       88.58     265.75     0
  102           1      0       13        11      0.02       47.54     309.00     0
  103           1      0       13        13      0.00        0.00       0.00     0
  104           1      0       12         9      0.01       37.33     149.33     0
  105           1      0       11         8      0.03       90.18     330.67     0
  106           1      0       11         9      0.01       28.09     154.50     0
  107           1      0        9         7      0.02       81.78     368.00     0
  108           1      0        8         8      0.00        0.00       0.00     0
 CNTR           2      0      130        29      0.16       42.49      54.69     0
 CAP1           2      0      111       104      0.01        2.52      40.00     0
 CAP2           1      0      150       149      0.00        0.08      12.00     0
 CAP3           1      0      150       150      0.00        0.00       0.00     0
 CAP4           2      0      622       569      0.04        2.02      23.68     0
```

```
STORAGE        CAP. REMAIN. MIN.  MAX.   ENTRIES AVL.   AVE.C.  UTIL.  RETRY DELAY

 CAP6            2      2     0     2      662    1     0.84  0.419    0     0
 CAP1            2      2     0     2      111    1     0.38  0.190    0     0
 CAP2            2      2     0     2      150    1     0.30  0.148    0     0
 CAP3            2      2     0     2      150    1     0.27  0.137    0     0
 CAP4            3      3     0     3      622    1     1.24  0.414    0     0
 CAP5            3      3     0     3      622    1     0.79  0.265    0     0
```

```
TABLE              MEAN       STD.DEV.  RETRY  RANGE                FREQUENCY   CUM. %
 CNTR              42.49       42.47     0
                                           -          0                29        22.31
                                         0 -         60                67        73.85
                                        60 -        120                26        93.85
                                       120 -        180                 7        99.23
                                       180 -        240                 1       100.00

 CAP1               2.52       11.72     0
                                           -          0               104        93.69
                                         0 -         30                 4        97.30
                                        30 -         60                 1        98.20
                                        60 -         90                 2       100.00

 CAP2               0.08        0.98     0
                                           -          0               149        99.33
                                         0 -         30                 1       100.00

 CAP3               0.00        0.00     0
                                           -          0               150       100.00

 CAP4               2.02        7.46     0
                                           -          0               569        91.48
                                         0 -         30                41        98.07
                                        30 -         60                12       100.00

TABLE              MEAN       STD.DEV.  RETRY  RANGE                FREQUENCY   CUM. %
 TOTAL37         4119.62      192.77     0
                                      3840 -       4080                35        53.85
                                      4080 -       4320                25        92.31
                                      4320 -       4560                 3        96.92
                                      4560 -       4800                 1        98.46
                                      5040 -       5280                 1       100.00

 TOTALT2         4735.92      168.64     0
                                      4320 -       4560                 8        12.31
                                      4560 -       4800                38        70.77
                                      4800 -       5040                14        92.31
                                      5040 -       5280                 4        98.46
                                      5280 -       5520                 1       100.00


TABLE              MEAN       STD.DEV.  RETRY  RANGE                FREQUENCY   CUM. %
 AREA1             88.58      175.34     0
                                           -          0                 8        66.67
                                         0 -        120                 1        75.00
                                       120 -        240                 1        83.33
                                       240 -        360                 1        91.67
                                       480 -        600                 1       100.00

 AREA2             47.54      162.31     0
                                           -          0                11        84.62
                                         0 -        120                 1        92.31
                                       480 -        600                 1       100.00

 AREA3              0.00        0.00     0
                                           -          0                13       100.00

 AREA4             37.33       89.90     0
                                           -          0                 9        75.00
                                         0 -        120                 2        91.67
                                        240 -      360          1      100.00

TABLE            MEAN      STD.DEV. PETRY  RANGE            FREQUENCY  CUM. %

 AREA5           90.18      170.55    0
                                           -         0          8       72.73
                                        120 -      240          1       81.82
                                        240 -      360          1       90.91
                                        480 -      600          1      100.00

 AREA6           28.09       80.23    0
                                           -         0          9       81.82
                                          0 -      120          1       90.91
                                        240 -      360          1      100.00

 AREA7           81.78      229.30    0
                                           -         0          7       77.78
                                          0 -      120          1       88.89
                                        600 -      720          1      100.00

 AREA8            0.00        0.00    0
                                           -         0          8      100.00
```

SCHEDULE 2A

```
FACILITY      ENTRIES  UTIL.   AVE. TIME AVAILABLE  OWNER PEND  INTER RETRY DELAY


  101            13   0.829    2225.08      1          0     0      0     0     0
  102            13   0.808    2171.62      1          0     0      0     0     0
  103            11   0.738    2344.91      1          0     0      0     0     0
  104            11   0.704    2235.36      1          0     0      0     0     0
  105             9   0.594    2307.56      1          0     0      0     0     0
  106             9   0.582    2259.11      1          0     0      0     0     0
  107             4   0.270    2359.00      1          0     0      0     0     0
  108             3   0.198    2306.33      1          0     0      0     0     0
 DANGE            4   0.074     651.00      1          0     0      0     0     0
 CNTR           104   0.210      70.64      1          0     0      0     0     0
 DUMY1           87   0.003       1.51      1          0     0      0     0     0
 DUMY2          112   0.000       0.00      1          0     0      0     0     0
 DUMY3          112   0.000       0.00      1          0     0      0     0     0
 DUMY4          494   0.013       0.99      1          0     0      0     0     0




QUEUE          MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME   AVE.(-0) RETRY


  101           1     0      13       13      0.00        0.00       0.00    0
  102           1     0      13       13      0.00        0.00       0.00    0
  103           1     0      11       11      0.00        0.00       0.00    0
  104           1     0      11       11      0.00        0.00       0.00    0
  105           1     0       9        9      0.00        0.00       0.00    0
  106           1     0       9        8      0.00        6.78      61.00    0
  107           1     0       4        4      0.00        0.00       0.00    0
  108           1     0       3        3      0.00        0.00       0.00    0
 CNTR           1     0     104       42      0.06       20.10      33.71    0
 CAP1           1     0      87       84      0.00        1.51      43.67    0
 CAP2           1     0     112      112      0.00        0.00       0.00    0
 CAP3           1     0     112      112      0.00        0.00       0.00    0
 CAP4           2     0     494      474      0.02        1.09      26.85    0




STORAGE           CAP. REMAIN. MIN.   MAX.  ENTRIES AVL.  AVE.C. UTIL.  RETRY DELAY


 CAP6               2      2      0      2     571    1    0.74  0.370    0     0
 CAP1               2      2      0      2      87    1    0.30  0.150    0     0
 CAP2               2      2      0      2     112    1    0.23  0.113    0     0
 CAP3               2      2      0      2     112    1    0.21  0.104    0     0
 CAP4               3      3      0      3     494    1    1.00  0.333    0     0
 CAP5               3      3      0      3     494    1    0.64  0.215    0     0
```

```
TABLE          MEAN      STD.DEV.  RETRY  RANGE            FREQUENCY  CUM. %
 CNTR          20.10       25.54     0
                                            -         0         42     40.38
                                         0  -        60         54     92.31
                                        60  -       120          8    100.00

 CAP1           1.51        9.32     0
                                            -         0         84     96.55
                                         0  -        30          1     97.70
                                        30  -        60          1     98.85
                                        60  -        90          1    100.00

 CAP2           0.00        0.00     0
                                            -         0        112    100.00

 CAP3           0.00        0.00     0
                                            -         0        112    100.00

 CAP4           1.09        5.58     0
                                            -         0        474     95.95
                                         0  -        30         13     98.58
                                        30  -        60          7    100.00
TABLE          MEAN      STD.DEV.  RETRY  RANGE            FREQUENCY  CUM. %
 TOTAL37     4126.77      153.26     0
                                      3840  -      4080         23     44.23
                                      4080  -      4320         24     90.38
                                      4320  -      4560          5    100.00

 TOTALT2     4688.27      110.42     0
                                      4320  -      4560          6     11.54
                                      4560  -      4800         33     75.00
                                      4800  -      5040         13    100.00

TABLE          MEAN      STD.DEV.  RETRY  RANGE            FREQUENCY  CUM. %
 AREA1          0.00        0.00     0
                                            -         0         13    100.00


 AREA2          0.00        0.00     0
                                            -         0         13    100.00


 AREA3          0.00        0.00     0
                                            -         0         11    100.00


 AREA4          0.00        0.00     0
                                            -         0         11    100.00


 AREA5          0.00        0.00     0
                                            -         0          9    100.00


 AREA6          6.78       20.33     0
                                            -         0          8     88.89
                                         0  -       120          1    100.00


 AREA7          0.00        0.00     0
                                            -         0          4    100.00

 AREA8          0.00        0.00     0
                                            -         0          3    100.00
```

SCHEDULE 3

```
FACILITY     ENTRIES  UTIL.    AVE. TIME AVAILABLE  OWNER PEND  INTER   RETRY DELAY


  101            15  0.794      2166.67      1          0    0      0      0      0
  102            12  0.637      2171.25      1          0    0      0      0      0
  103            12  0.640      2183.33      1          0    0      0      0      0
  104            10  0.555      2271.60      1          0    0      0      0      0
  105             9  0.488      2219.78      1          0    0      0      0      0
  106             7  0.397      2320.14      1          0    0      0      0      0
  107             5  0.279      2282.60      1          0    0      0      0      0
  108             5  0.270      2213.80      1          0    0      0      0      0
 DANGE            3  0.028       389.00      1         45    0      0      0      0
 CNTR            99  0.166        68.76      1          0    0      0      0      0
 DUMY1           80  0.007         3.95      1          0    0      0      0      0
 DUMY2          106  0.002         0.86      1          0    0      0      0      0
 DUMY3          106  0.000         0.00      1          0    0      0      0      0
 DUMY4          471  0.011         0.99      1          0    0      0      0      0




QUEUE             MAX  CONT. ENTRIES ENTRIES(0) AVE.CONT. AVE.TIME  AVE.(-0) RETRY


  101               1     0       15         14     0.01      20.00    300.00     0
  102               1     0       12         12     0.00       0.00      0.00     0
  103               1     0       12         11     0.01      40.50    486.00     0
  104               1     0       10          8     0.02      75.70    378.50     0
  105               1     0        9          7     0.03     118.11    531.50     0
  106               1     0        7          5     0.03     183.29    641.50     0
  107               1     0        5          3     0.02     154.80    387.00     0
  108               1     0        5          4     0.01      43.40    217.00     0
 CNTR               3     0       99         43     0.06      23.82     42.11     0
 CAP1               3     0       80         74     0.01       5.46     72.83     0
 CAP2               1     0      106        103     0.00       0.86     30.33     0
 CAP3               1     0      106        106     0.00       0.00      0.00     0
 CAP4               2     0      471        451     0.01       1.16     27.35     0




STORAGE            CAP. REMAIN. MIN.   MAX.   ENTRIES AVL.   AVE.C.   UTIL.  RETRY DELAY


 CAP6                 2      2      0      2      515    1     0.56   0.281     0     0
 CAP1                 2      2      0      2       80    1     0.24   0.119     0     0
 CAP2                 2      2      0      2      106    1     0.18   0.092     0     0
 CAP3                 2      2      0      2      106    1     0.17   0.084     0     0
 CAP4                 3      3      0      3      471    1     0.81   0.271     0     0
 CAP5                 3      3      0      3      471    1     0.52   0.174     0     0
```

```
TABLE           MEAN      STD.DEV. RETRY  RANGE            FREQUENCY  CUM. %
 CNTR           33.52      32.66     0
                                         -       0              43      43.43
                                      0  -      60              43      86.87
                                     60  -     120              11      97.98
                                    120  -     180               2     100.00

 CAP1            5.46      21.81     0
                                         -       0              74      92.50
                                     30  -      60               2      95.00
                                     60  -      90               2      97.50
                                     90  -     120               1      98.75
                                    120  -     150               1     100.00

 CAP2            0.86       5.71     0
                                         -       0             103      97.17
                                      0  -      30               2      99.06
                                     30  -      60               1     100.00

 CAP3            0.00       0.00     0
                                         -       0             106     100.00

 CAP4            1.16       6.34     0
                                         -       0             451      95.75
                                      0  -      30              16      99.15
                                     30  -      60               2      99.58
                                     60  -      90               2     100.00


TABLE           MEAN      STD.DEV. RETRY  RANGE            FREQUENCY  CUM. %
 TOTAL37      4116.32     150.71     0
                                   3840  -    4080              25      43.86
                                   4080  -    4320              27      91.23
                                   4320  -    4560               4      98.25
                                   4560  -    4800               1     100.00

 TOTALT2      4719.33     118.58     0
                                   4320  -    4560               6      14.29
                                   4560  -    4800              23      69.05
                                   4800  -    5040              13     100.00


TABLE           MEAN      STD.DEV. RETRY  RANGE            FREQUENCY  CUM. %
 AREA1          20.00      77.46     0
                                         -       0              14      93.33
                                      0  -     300               1     100.00

 AREA2           0.00       0.00     0
                                         -       0              12     100.00

 AREA3          40.50     140.30     0
                                         -       0              11      91.67
                                    300  -     600               1     100.00

 AREA4          75.70     160.78     0
                                         -       0               8      80.00
                                    300  -     600               2     100.00

 AREA5         118.11     311.87     0
                                         -       0               7      77.78
                                      0  -     300               1      88.89
                                    900  -    1200               1     100.00
```

```
TABLE                MEAN       STD.DEV. RETRY  RANGE             FREQUENCY  CUM. %
 AREA6              183.29       314.84   0
                                                 -          0          5       71.43
                                          300 -           600          1       85.71
                                          600 -           900          1      100.00

 AREA7              154.80       230.21   0
                                                 -          0          3       60.00
                                            0 -           300          1       80.00
                                          300 -           600          1      100.00

 AREA8               43.40        97.05   0
                                                 -          0          4       80.00
                                            0 -           300          1      100.00
```

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